Extraction of the Mandibular Third Molar

An Evidence-based Guide

Joe Iwanaga · Shogo Kikuta
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Foreword

Third molar extractions represent a significant technical and surgical challenge in their management and the importance of evaluating the preoperative indications—such as the appropriate anesthesia and injuries to peripheral nerves, cannot be overstated.

While avoiding extractions of wisdom teeth has been associated with the development of pathological lesions as well as detrimental periodontal outcomes and structural integrity to adjacent teeth, the surgical procedure itself may have potential morbidities.

This book by Professor Iwanaga and colleagues represents a comprehensive and updated review of the anatomy, radiology, and epidemiology of third molars, inclusive of an in-depth analysis of surgical techniques and complications, as well as illustrative clinical case presentations.

Regarding the qualifications of the author and editor, Professor Iwanaga has a unique combination of skills and knowledge as a trained Oral and Maxillofacial Surgeon with a PhD in Clinical Anatomy. He has dedicated his admirable academic career to pursuing excellence in research and his commitment to education has motivated him to share his findings with the professional community through the publication of hundreds of articles and books. With this book, Professor Iwanaga provides a foundational asset for those seeking a reference book on the Extraction of the Mandibular Third Molar.

I feel a deep sense of honor to endorse this contribution as a guidance for future generations of dental professionals, surgeons, and clinical researchers.

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Preface

The extraction of the mandibular third molar is often considered a routine procedure in dental and oral surgery, yet it remains one of the most complex and nuanced operations performed in the field. This procedure requires not only technical expertise but also a deep understanding of the underlying anatomy, pathology, imaging, and scientific evidence. Despite its frequency—over 10 million third molars extracted annually in the United States—there is a surprising lack of comprehensive resources that address the full spectrum of knowledge required for safe and effective treatment.

This book aims to bridge that gap by providing a holistic, evidence-based approach to mandibular third molar extraction. We have designed it to go beyond procedural steps, offering detailed insights into the anatomy of the mandible, common pathological conditions, the latest imaging techniques, and emerging research that informs clinical practice. Our goal is to equip dental and medical professionals with not only the "how" but also the "why" behind each decision made during third molar extractions, ultimately improving patient care while reducing risks and complications.

The decision to focus on mandibular third molar extraction was driven by several key factors. It remains one of the most commonly performed yet litigious procedures in dentistry, with complications such as nerve damage or infection continuing to occur, often due to outdated practices or lack of updated knowledge. Moreover, with the rise of advanced imaging technologies and surgical innovations, there is a clear need for a more comprehensive understanding of the procedure, grounded in current research and clinical experience.

Unlike many existing resources that focus narrowly on technique, this book takes a broader, multidisciplinary approach. We combine sophisticated anatomical diagrams, cutting-edge radiographic images, scientific data, and real-world case studies, providing both novice and experienced practitioners with valuable insights. Each chapter is carefully crafted to help refine surgical skills while promoting critical thinking, clinical judgment, and a deeper understanding of the scientific principles at play.

Our intended audience includes general dentists, oral surgeons, periodontists, residents in oral surgery, dental students, and medical professionals such as anatomists, head and neck surgeons, and ENT specialists. We also aim to support dental hygienists, nurses, and surgical assistants who work alongside oral surgeons in the

operating room. By integrating the latest research and clinical examples, we hope to foster both technical proficiency and a comprehensive approach to third molar surgery.

As the demand for mandibular third molar extractions continues to rise, so too does the need for a more sophisticated understanding of the procedure. We are confident that the knowledge within these pages will improve patient outcomes, minimize complications, and lay the groundwork for future advances in oral and maxillofacial surgery.

We invite you to explore this work and hope it serves as an invaluable resource for students, educators, practitioners, and anyone interested in mastering the complexities of mandibular third molar extraction.

New Orleans, LA, USA Joe Iwanaga

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Part I

Basics for the Mandibular Third Molar

1 Clinical Anatomy of the Impacted Mandibular Third Molar Extraction

Joe Iwanaga, Kisho Ono, Norio Kitagawa, and R. Shane Tubbs

Introduction

Knowledge of the regional anatomy of the third mandibular molar is important for extraction of this tooth, especially, when it is impacted. The morphology of the mandible and the structure of the surrounding soft tissues are very complicated, and this anatomy can be challenging to visualize. In this chapter, the anatomy associated with the mandibular third molar will be discussed.

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Anatomy of the Mandibular Third Molar Tooth

In this section, we show the formation of mandibular third molars and root anatomy. It is very important to know the stages of tooth formation, especially root formation, in order to determine the timing of tooth extraction.

Formation of the Mandibular Third Molar

There have been many studies on the staging of the formation of the mandibular third molar. Moorrees et al. created a classification of the stages of tooth formation (Moorrees et al. 1963). The formation stage of the mandibular molars can be roughly divided into stage C (crown formation), stage R (root formation), and stage A (apex closure). Stage C is less associated with the extraction, but stages R and A need to be discussed. Stage R is divided into six parts: Ri (initial root formation), Cli (initial cleft formation), R¼ (root length ¼), R½ (root length ½), R¾ (root length ¾), and Rc (root length complete). Stage A is divided into two parts: A½ (apex ½ closed) and Ac (apex closure complete) (Fig. 1.1).

Liversidge reported a study on the formation of the mandibular third molar with a comprehensive literature review (Liversidge 2008). The following is a synopsis of that review (there is considerable variation by ethnicity and sex).

The formation of the mandibular third molar crown begins at approximately 12 to 13 years of age. The root formation stage (Ri) also begins between the late 12 to early 14 years of age. The root cleft formation (Rcl) is considered to be in the mid-13 to early 15 years of age. The tooth root is half of its maximum length around 15 to 17 years of age (R½). The root length complete (Rc) and apex ½ closed (A½) occur between 16 and 19 years of age with the latest ages averaging 22 years for males and 24 years for females, according to a report from Turkey (Sisman et al. 2007). Although the average age of apex closure complete (Ac) is 19 to 20 years, Levesque et al. (1981) found that 90% of females had apex closure completed by the

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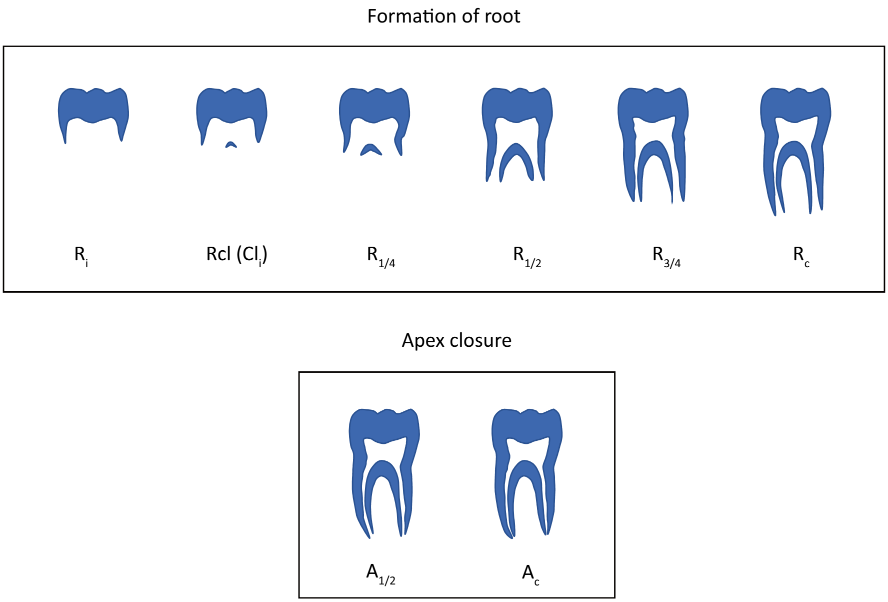


Fig. 1.1 Root formation of the mandibular third molar. Stages of formation based on Moorrees

age of 24 years, and Nyström et al. (2007) found that 97% of females had apex closure complete by the age of 24 years (Levesque et al. 1981; Nyström et al. 2007). Many studies have shown that the mean age at each stage is slightly less in males than in females. In particular, root length completion (up to apex closure) was all completed by age of 24 years in males but not entirely completed in females (Levesque et al. 1981). These findings show that in the majority of cases, the mandibular third molar apex is completely closed by the age of 24 years, which can be applied to determining the timing of the extraction.

Number of Roots

The number of mandibular third molar roots has been studied in various countries and ethnicities. In all studies including Japanese, Iranians, Koreans, Indians, and Brazilians, double roots were the most common, followed by single root and then triple roots (Fujita and Kirino 1976; da Silva Sampieri et al. 2018; Kuzekanani et al. 2012; Park et al. 2013; Somasundaram et al. 2017) (Fig. 1.2, Table 1.1). In clinical practice, some of these that appear to be single root (or unclear) on panoramic radiographs may be found to be multiple roots during the extraction procedure. In other words, even if it looks like a single root on the panoramic radiograph, we cannot rule out the possibility that it has double roots.

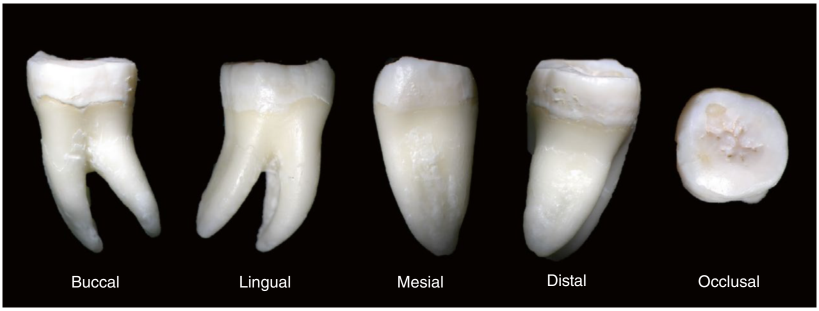


Fig. 1.2 Mandibular third molar with double roots

Table 1.1 Number of roots in different studies

Year	Author	Country	Material	Number studied	Single root	Double root	Triple root
1976	Fujita	Japan	Unknown	Unknown	30%	59%	11%
2012	Kuzekanani	Iran	Extracted tooth	154	21.0%	73.0%	5.5%
2013	Park	Korea	CBCT	214	37.9%	56.5%	1.9%
2017	Somasundaram	India	CBCT	171	12.9%	84.2%	2.3%
2018	da Silva Sampieri	Brazil	Panoramic radiography	1205	1.5%	98.3%	0.2%

Fig. 1.3 Submucosal impacted mandibular third molar



Mandibular Third Molar and its Impacted State

The impacted state of mandibular third molars varies from submucosal impaction to complete impaction inside the bone. In cases of submucosal impaction, mucosal incision and tooth splitting might be necessary, but bone removal could be minimum (Fig. 1.3). In case of complete impaction, a large amount of bone removal may be

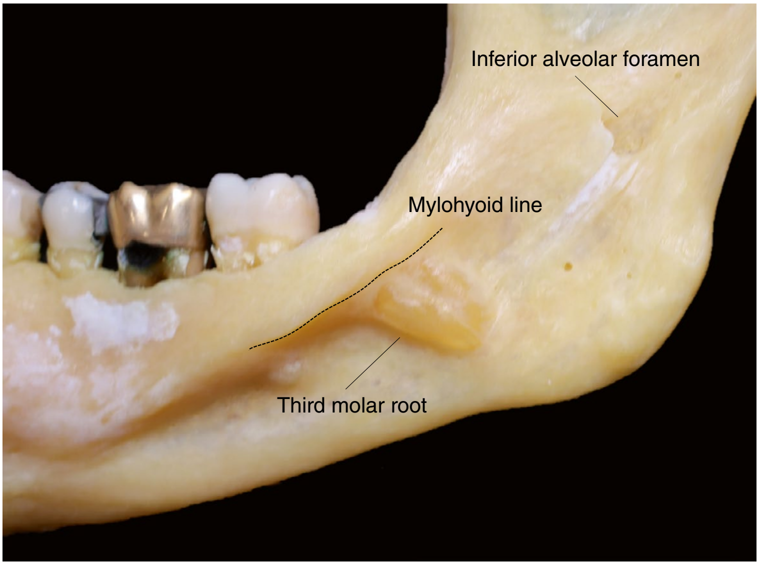


Fig. 1.4 Lingual view of an impacted mandibular third molar. Note that the lingual cortical bone of the root of the third molar is very thin

required, and the position of the root is often deep and below the mylohyoid muscle line. Therefore, the distance from the root to the lingual cortical bone tends to be short (due to the concavity of the submandibular fossa), and the root often perforates the cortical bone. If we put too much force in the wrong direction, this could result in displacement of the tooth fragment into the floor (Fig. 1.4). A complete horizontally impacted mandibular third molar has a risk of displacement not only of the tooth root but also of the tooth crown into the floor of the mouth (Fig. 1.5). In those cases, excessive bone removal might be required. Even if the tooth is not completely impacted in the bone, if the tooth is inclined buccolingually, the lingual cortical bone could be like a bony bridge and may fracture by excessive force (Fig. 1.6).

Lingual Nerve

The lingual nerve is a branch of the mandibular nerve and responsible for the perception of the anterior two-thirds of the tongue (the gustatory fibres are from the chorda tympani derived from the facial nerve). The lingual nerve runs anteriorly and inferiorly along the anteromedial to the inferior alveolar nerve in the pterygomandibular space, crosses the anterior border of the medial pterygoid muscle, passes under the superior pharyngeal constrictor muscle, and enters the floor of the mouth. When passing under the superior pharyngeal constrictor muscle, it passes just

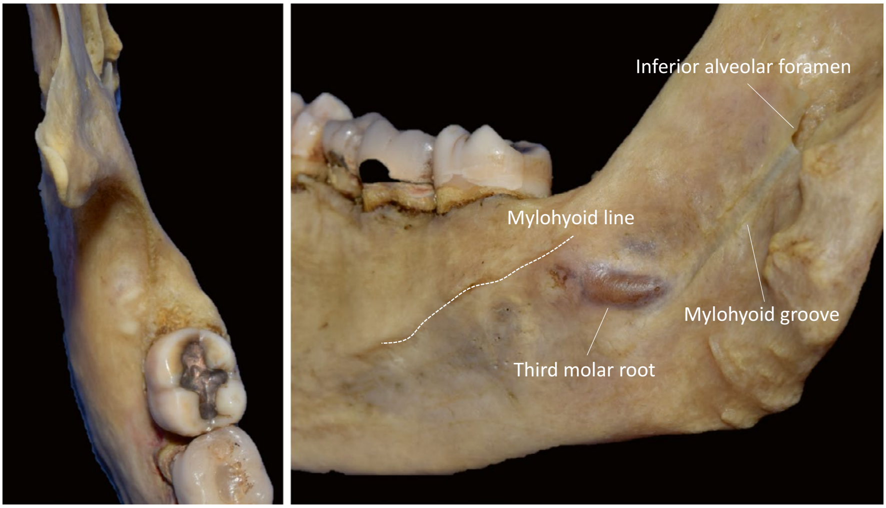


Fig. 1.5 Completely impacted mandibular third molar

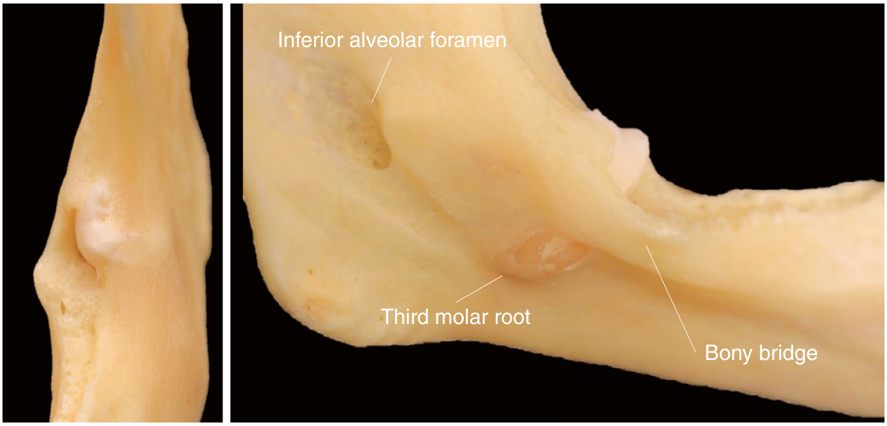


Fig. 1.6 Lingual cortical bony bridge

medial to the lingual cortical bone. After that, it runs forward in the floor of the mouth on the mylohyoid muscle and changes direction towards the tongue near the first and second molars (Figs. 1.7, 1.8 and 1.9). The distance between the lingual nerve and the lingual cortical bone has been measured in previous studies. However, it is important to understand the following more than its distance: (1) The lingual nerve runs adjacent to the periosteum in the third molar area. (2) The lingual nerve moves with the movement of the tongue (Figs. 1.10 and 1.11).

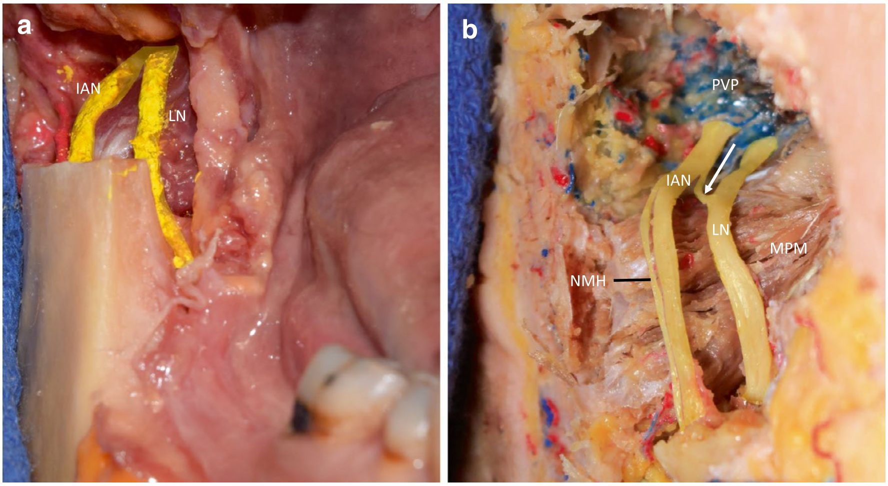


Fig. 1.7 Lingual nerve (LN) and inferior alveolar nerve (IAN) in the right pterygomandibular space. (**a**) Oblique view. LN travels anteromedial to the IAN. Note the ramus of the mandible above the mandibular foramen is removed. (**b**) Lateral view. Note the entire ramus of the mandible is removed. Communicating branch between LN and IAN (arrow); NMH, nerve to mylohyoid muscle; PVP, pterygoid venous plexus

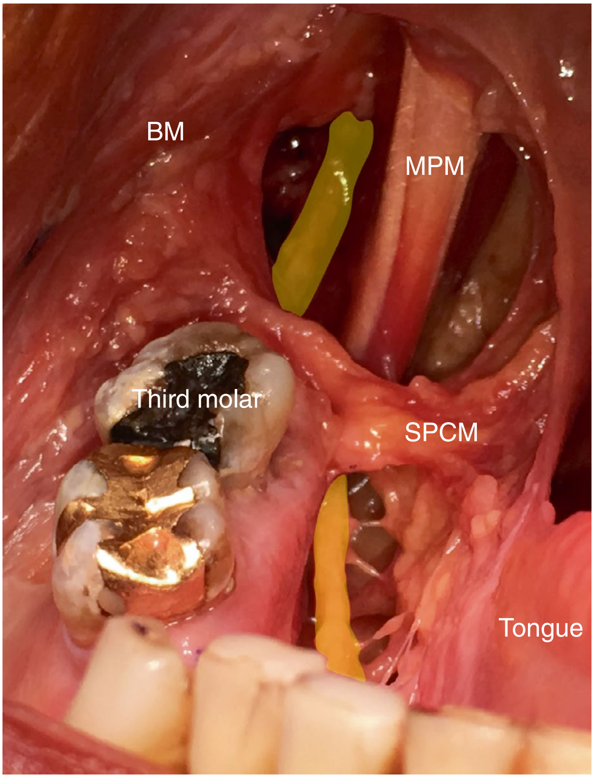


Fig. 1.8 Lingual nerve course in the right pterygomandibular and sublingual spaces. *Bm* bucinator muscle, *MPM* medial pterygoid muscle, *SPCM* superior pharyngeal constrictor muscle

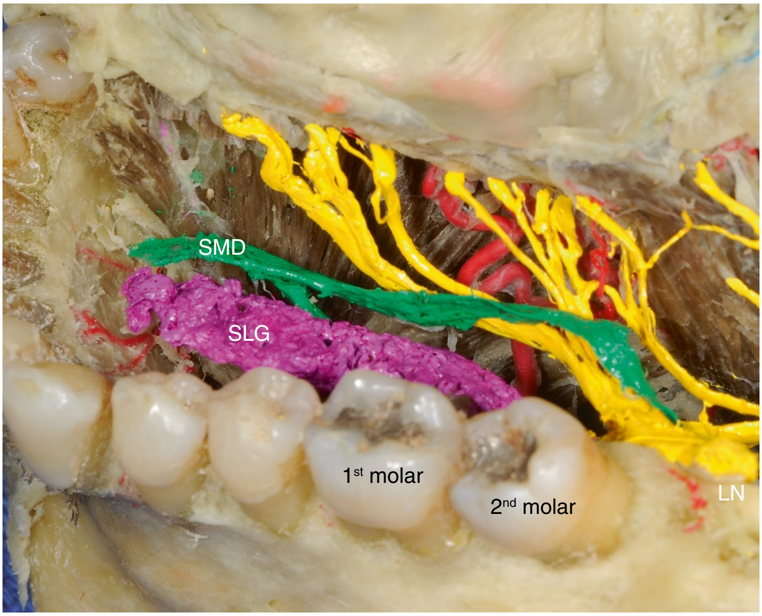


Fig. 1.9 Lingual nerve (LN) course in the left sublingual space. *SLG* sublingual gland, *SMD* submandibular gland

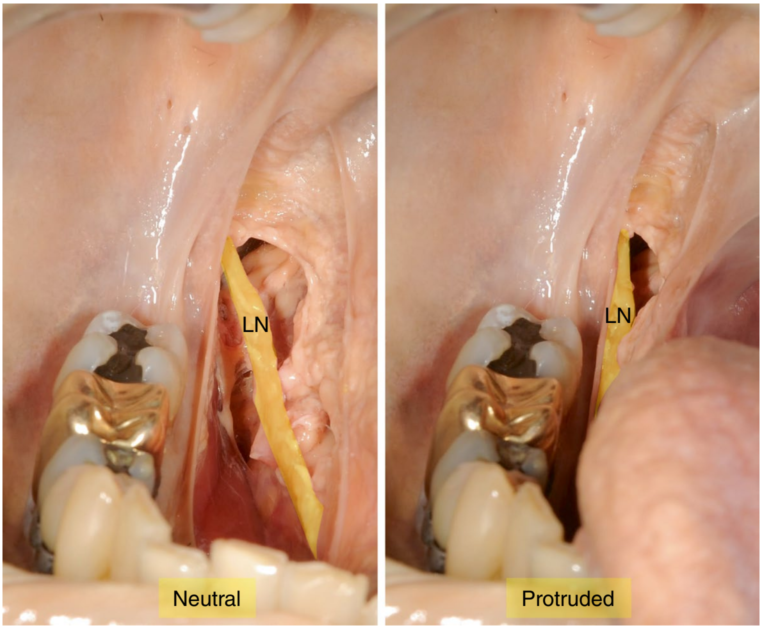


Fig. 1.10 Lingual nerve movement following tongue position in cadaveric specimens (neutral and protruded positions)

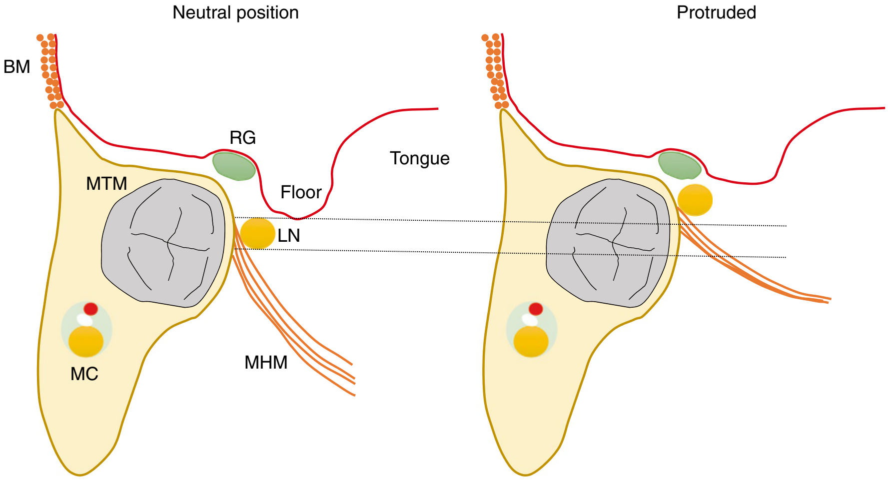


Fig. 1.11 Lingual nerve movement following tongue position in coronal sections (neutral and protruded positions). *BM* buccinator muscle, *LN* lingual nerve, *MC* mandibular canal, *MHM* mylohyoid muscle, *MTM* mandibular third molar, *RG* retromolar gland

Mandibular Morphology and the Lingual Nerve

The retromolar triangle is the triangular area distal to the last molar of the mandible. In this area, the retromolar pad is observed as a soft tissue, and the retromolar triangle and retromolar fossa as bony structures. More importantly, there is essentially no bone lining directly beneath the retromolar pad.

The retromolar pad, located posterior to the last molar, is not lined by bone (Fig. 1.12). In general, impacted mandibular third molars are often located inside the bone between the internal and external oblique lines (Fig. 1.13). The internal and external oblique lines run posteriorly and laterally from the mandibular second molar, forming the anterior margin of the ramus of the mandible. A distal incision from the mandibular second molar needs to go laterally not posteriorly, because it could damage the medial pterygoid muscle and more importantly the lingual nerve that enters the floor of the mouth through the pterygomandibular space (Fig. 1.14). A posterior incision always needs to be made laterally (buccally) on the bony surface after palpating the bone form with your fingers.

Fig. 1.12 Terminology for anatomical structures in the retromolar area

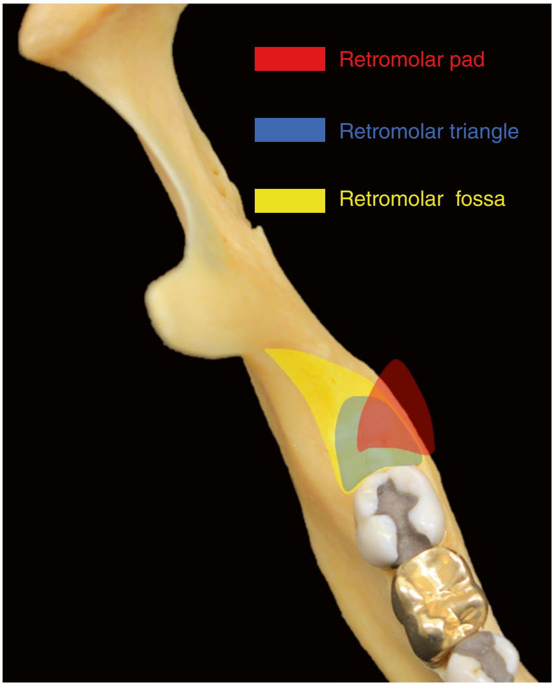
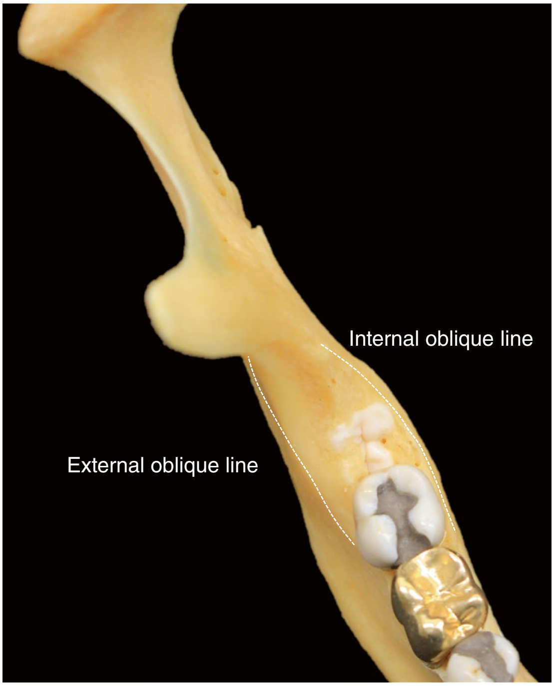


Fig. 1.13 Location of the impacted third molar



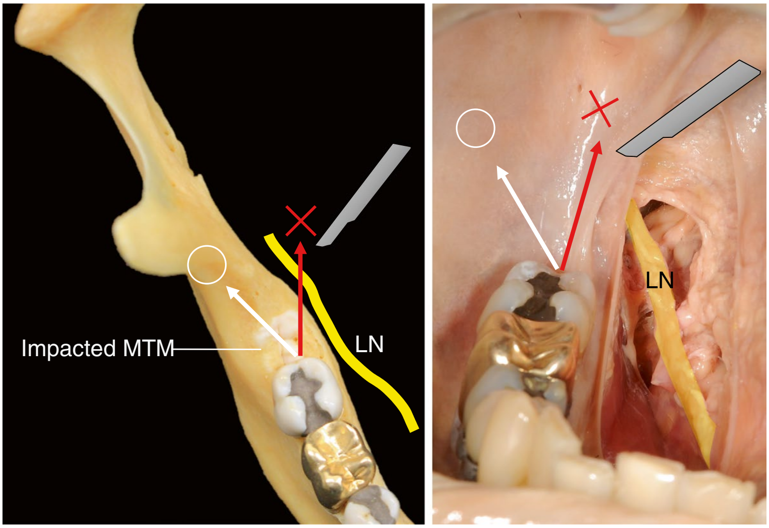


Fig. 1.14 A distal incision from the mandibular second molar. Note that the posterior incision could damage the LN. *LN* lingual nerve, *MTM* mandibular third molar

Mandibular Canal

The mandibular canal travels through the mandible and contains the inferior alveolar nerve and inferior alveolar vessels. The official terminology for this structure is the mandibular canal, but clinicians often refer to it as the inferior alveolar canal (FIPAT 2019; Iwanaga and Matsushita, et al. 2020, Iwanaga and Shiromoto et al. 2020). In general, the mean diameter of the mandibular canal is 2.5 mm, and the nerve occupies the largest proportion of the canal with a mean of 1.8 mm (Kilic et al. 2010). Of the three structures (nerve, artery, and vein), the nerve commonly runs in the lowest position, but there are many variations (Figs. 1.15 and 1.16) (Matani et al. 2014). Therefore, even if we assume that only the upper wall of the mandibular canal is injured, it is quite possible that the inferior alveolar nerve is also injured.

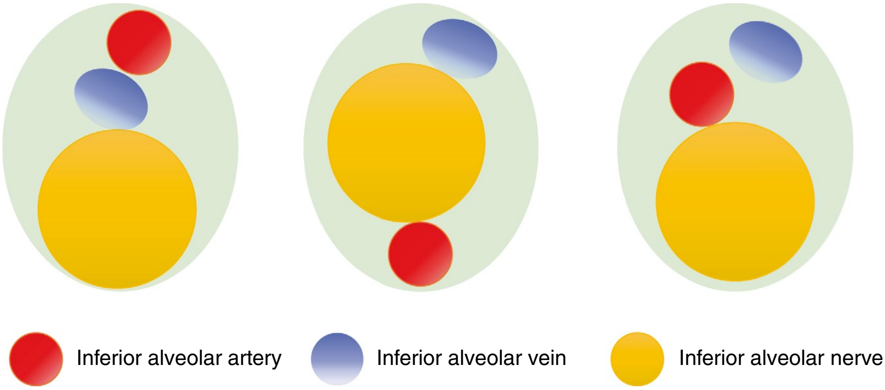


Fig. 1.15 Variable patterns of the contents of the mandibular canal

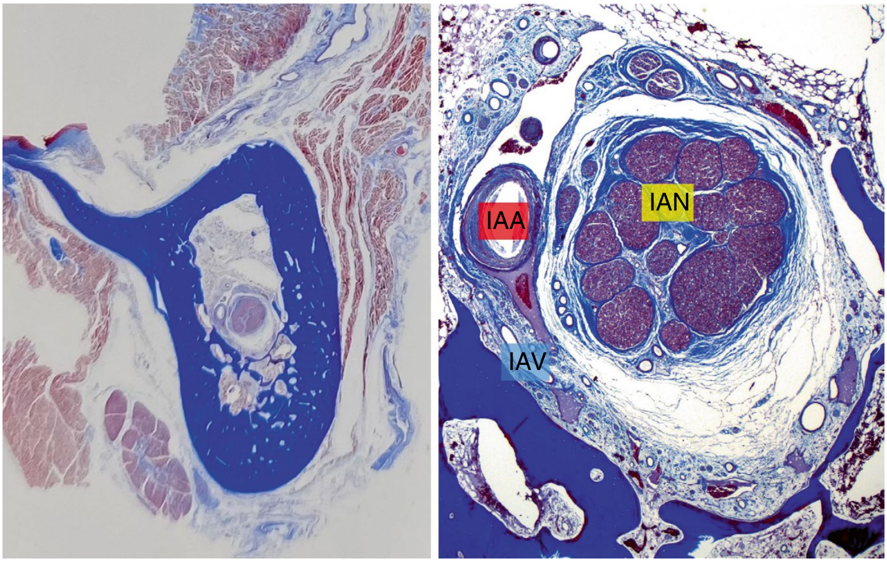


Fig. 1.16 Histology of the mandibular canal in the molar area. Note that the inferior alveolar nerve (IAN) is located above the inferior alveolar artery (IAA) and vein (IAV)

Retromolar Foramen

The retromolar foramen is in the retromolar area, which is an exit of the retromolar canal which contains a neurovascular bundle (Fig. 1.17). In studies using cone-beam computed tomography (CBCT), the frequency of occurrence has varied widely from 5 to 75%, but in reality, it is thought to be about 20 to 30% (Motamedi et al. 2016; Truong et al. 2017). If there is a nerve, it is thought that a branch of the

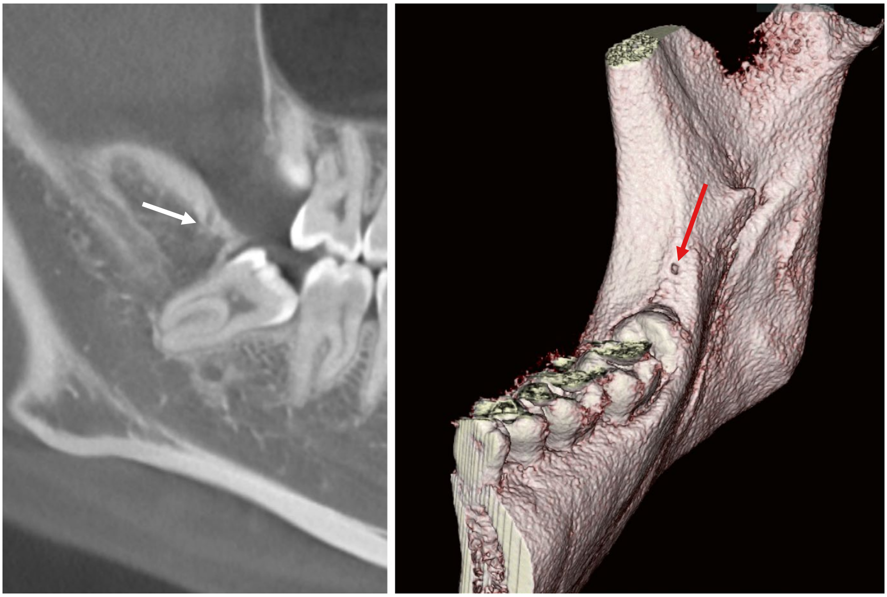


Fig. 1.17 Retromolar canal (white arrow) and foramen (red arrow)

inferior alveolar nerve passes through the retromolar canal and supplements part of the area innervated by the buccal nerve. The retromolar foramen may be damaged by incisions or mucosal detachment in the distal buccal direction during tooth extraction. Paresthesia of the buccal mucosa due to damage to a large retromolar foramen (diameter of 2.3 mm) has been reported (Kikuta et al. 2018).

Buccal Nerve

The buccal nerve is one of the branches of the anterior division of the mandibular nerve. It innervates the buccal gingiva, alveolar mucosa, buccal mucosa, and buccal skin. Knowledge of the buccal nerve is important for both buccal injections and inferior alveolar nerve anaesthetic blockade (Fig. 1.18).

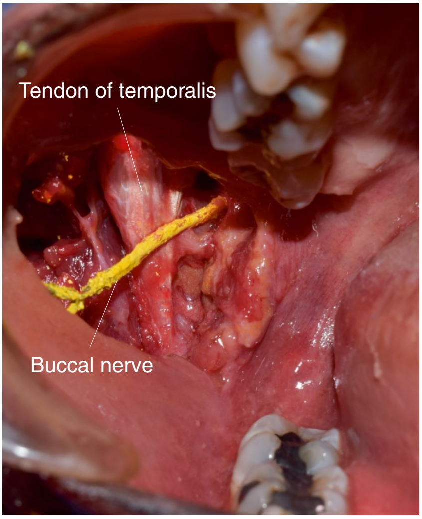


Fig. 1.18 Buccal nerve course

Facial Artery

Although the relationship between the facial artery and extraction of an impacted third molar has rarely been discussed, injury of the facial artery can occasionally lead to serious complications. For example, there are reports of injury to the facial artery during extraction of the mandibular third molar resulting in a pseudoaneurysm and bleeding (de Lucas et al. 2008; Pukenas et al. 2012). The facial veins also run anterior nearby and can bleed if injured.

When we raise a mucoperiosteal full-thickness flap on the buccal side of the mandible, the main trunk of the facial artery and the inferior labial artery are just adjacent to the periosteum. Most anatomy textbooks only show the facial artery running superficially on the face, and an intraoral view of the facial artery is rarely depicted (Figs. 1.19 and 1.20) (Iwanaga et al. 2020a, b).

In our recent study using computed tomography, the mean horizontal distance from the buccal cortical bone to the facial artery at the third molar area was around 2 mm (Takeshita et al. 2021). If the buccal cortical bone is perforated and the periosteum is broken from the inside during crown separation, the facial artery might be damaged. In most cases, the facial artery runs very low at this location (Fig. 1.21).

Fig. 1.19 Traditional cadaveric image of the facial artery

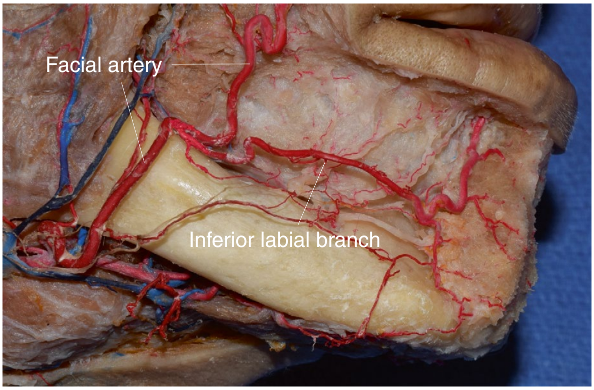


Fig. 1.20 Intraoral dissection of the facial artery

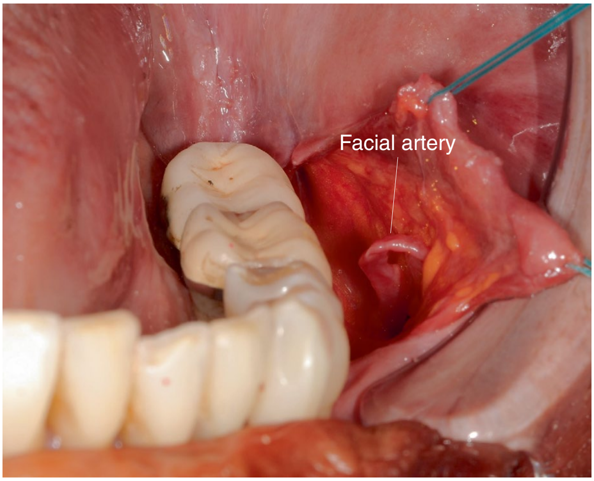
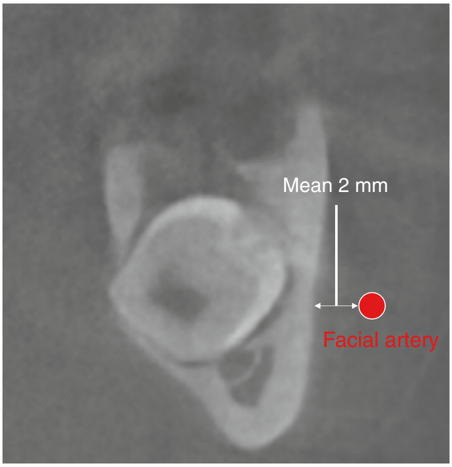


Fig. 1.21 Positional relationship of the facial artery and mandibular third molar on CT



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2 Radiologic Signs on Panoramic Radiography and CBCT

Yohei Takeshita, Joe Iwanaga, and Junichi Asaumi

Introduction

Mandibular third molar extraction can cause paresthesia by intraoperative damage to the inferior alveolar nerve (IAN). The risk of paresthesia increases when the mandibular canal (MC) and the root are close or contact directly (Kipp et al. 1980; Monaco et al. 2004). Therefore, it is very important to evaluate both the position and relationship between the mandibular third molar and the MC accurately before operation.

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Importance of Screening of the Mandibular Canal with Panoramic Images

Image examination is useful and essential for the preoperative evaluation of mandibular third molar extraction. As the first option for image examination, plain imaging such as periapical (intraoral) or panoramic radiography is often used. Periapical images are useful for observing the form of the tooth and adjacent structures; however, it can be difficult to place the film accurately due to the deep position of the mandibular third molar, and this is even more difficult when it is impacted. Therefore, a part of the mandibular third molar and MC is more likely to be out of focus. Panoramic images can provide information about the relationship between the mandibular third molar and the MC regardless of the condition of the third molar. Although panoramic images are not three-dimensional but two-dimensional same as the periapical images, they are most frequently used as the first choice for screening. A lot of studies have been conducted to assess the panoramic signs and classification systems of the relationship between the mandibular third molar and the MC in order to reduce the risk of paraesthesias caused by extraction procedures (Miclotte et al. 2015; Sedaghatfar et al. 2005; Maegawa et al. 2003; Howe and Poyton 1960; Rood and Shehab 1990; Bell et al. 2003; Bell 2004).

Panoramic Signs and Classification System

Rood Signs

Rood and Shehab (1990) reported seven panoramic signs of the relationship between the mandibular third molar and the MC: darkening of the root, deflection of the root, dark and bifid apex of the root, narrowing of the root, diversion of the MC, interruption of the white line of the MC, and narrowing of the MC (Fig. 2.1 and Table 2.1). Rood and Shehab concluded that there were three significant signs related to the postoperative paresthesia caused by IAN injury: darkening of the root, diversion of the MC, and interruption of the white line of the MC.

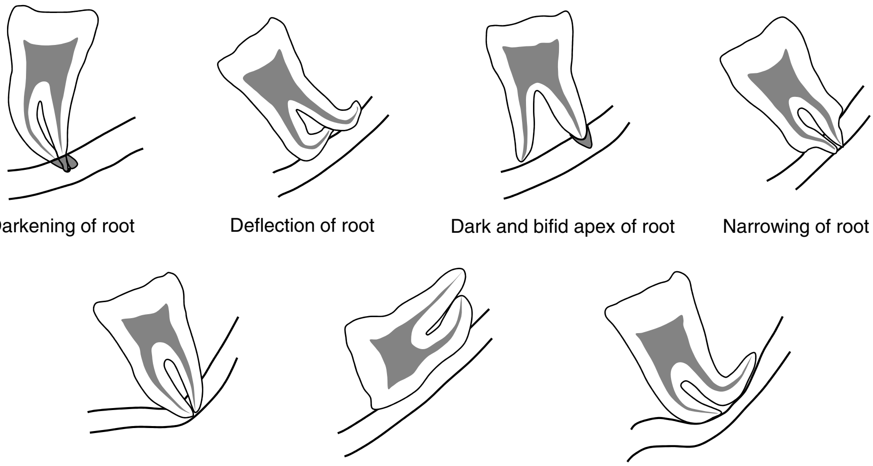


Fig. 2.1 Seven panoramic signs of the relationship between the mandibular third molar and the mandibular canal (Rood and Shehab 1990)

Table 2.1 Panoramic signs of a relationship between the mandibular third molar and the mandibular canal (Rood and Shehab 1990)

Panoramic signs	Description
Darkening of root	Radiopaque of the mandibular third molar root, where mandibular canal is superimposed
Deflection of root	Root morphology of the mandibular third molar, where mandibular canal is contact or superimposed
Dark and bifid apex of root	Darkening and bifid of the mandibular third molar root, where mandibular canal is superimposed
Narrowing of root	Narrowing of the mandibular third molar root, where the mandibular canal is contact or superimposed
Diversion of the mandibular canal	Direction change of the mandibular canal, where the mandibular third molar root is crossed
Interruption of white line of the mandibular canal	Interruption of continuity of the mandibular canal cortex
Narrowing of the mandibular canal	Narrowing of the mandibular canal, where the mandibular third molar root is contact or superimposed

Pell and Gregory Classification

Pell and Gregory (1933) classified the mandibular third molar into classes I, II, and III according to the distance between the distal border of the second molar and the anterior border of the mandibular ramus. They also classified the mandibular third molar into position A, B, and C according to the depth from the occlusal plane to the cervical line of the second molar (Fig. 2.2 and Table 2.2). Although the position of the MC is not evaluated in this classification, the mandibular third molar tends be located closer to the MC at higher classification stages.

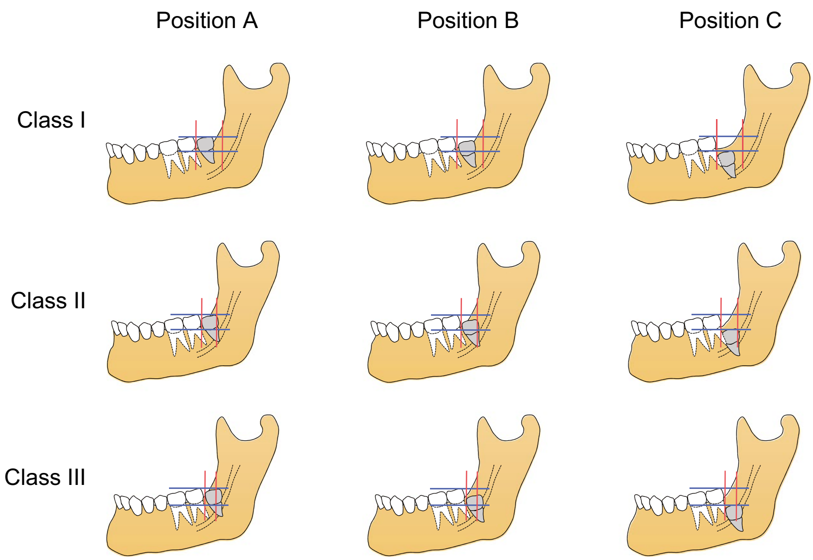


Fig. 2.2 Pell and Gregory classification. The impacted mandibular third molar is classified according to the distance between the distal border of the second molar and the anterior border of the ramus (Pell and Gregory 1933)

Table 2.2 Pell and Gregory classification for impacted mandibular third molar (Pell and Gregory 1933)

Variable	Description
Class I	Sufficient space between the distal surface of the second molar and the anterior border of the ramus for eruption of the third molar
Class II	Space between distal surface of the second molar and anterior border of the ramus is less than the mesiodistal diameter of the third molar
Class III	The third molar is totally impacted in the bone of the anterior border of the ramus because of absolute lack of space
Position A	Highest part of the impacted third molar is level with or above the occlusal plane
Position B	Highest part of the impacted third molar is below the occlusal plane but above the cervical line of the second molar
Position C	Highest part of the impacted third molar is below the cervical line of the second molar

Winter Classification

The Winter classification (Winter 1926) is used to classify an impacted mandibular third molar based on its position to the long axis of the second molar: vertical, horizontal, mesioangular, distoangular, buccoangular, linguoangular, transverse, and inverse (Fig. 2.3 and Table 2.3). As the position of the MC is not evaluated in this classification, it should not be used to assess the risk of IAN injury.

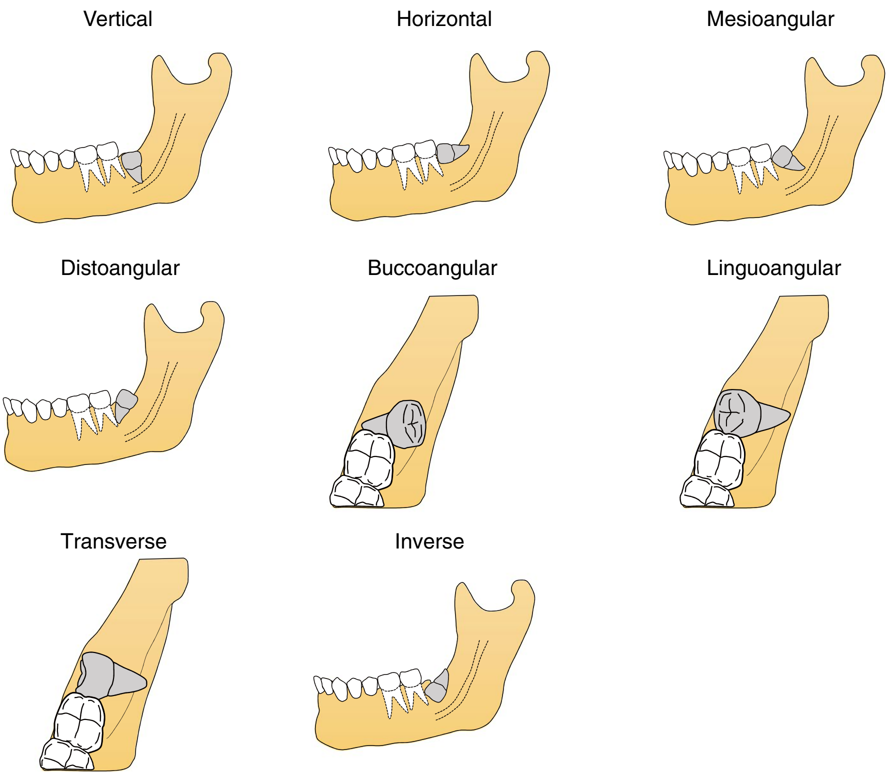


Fig. 2.3 Winter classification. The impacted mandibular third molar is classified based on its angulation (Winter 1926)

Table 2.3 Winter classification for impacted mandibular third molar (Winter 1926)

Impaction type	Description
Vertical	Long axis of the third molar is parallel to the long axis of the second molar
Horizontal	Long axis of the third molar is horizontal
Mesioangular	Impacted tooth is titled towards the second molar in a mesial direction
Distoangular	Long axis of the third molar is angled distally or posteriorly away from the second molar
Buccoangular	Combined with the previous factors, the tooth can be buccally (tilted towards the cheek) impacted
Linguoangular	Combined with the previous factors, the tooth can be lingually (tilted towards the tongue) impacted
Transverse	The tooth is horizontally impacted in a cheek-tongue direction
Inverse	The tooth is reversed and positioned upside down

Clinical Value and Characteristic of CBCT for Preoperative Evaluation

Image diagnosis is an essential part of successful treatment. Therefore, an accurate diagnosis should be made before treatment. Panoramic radiography is often used as the first option in confirming the position and relationship between the mandibular third molar and the MC; however, three-dimensional information such as the buccolingual relationship cannot be provided. When the contact of the mandibular third molar and the MC is suspected on the panoramic image, cone beam computed tomography (CBCT) or multidetector computed tomography (MDCT) is recommended for further evaluation. CBCT and MDCT can provide additional useful three-dimensional information of the position of the mandibular third molar and the MC. Differences between CBCT and MDCT are shown in Table 2.4. The two main differences are the radiation dose and the spatial resolution. Regarding the radiation dose, the levels for CBCT are greater than with a panoramic radiography (2-240 x as much as a panoramic radiograph) (Jacobs 2011), whereas those for CBCT are much lower than in MDCT (one-eighth to one-tenth lower than MDCT) (Tsiklakis et al. 2005). However, it is considered that the radiation dose levels for CBCT of the mandibular third molar on one side ranged from 10 to 20μSv when the field of view (FOV) is optimized, which is also much lower than the worldwide average natural radiation dose to humans per year (2.4 mSv) (Thorne 2003). On the other hand, not only the adjustment of the FOV but also that of the tube voltage and tube current is effective for dose reduction. However, if tube voltage and tube current are very low, the images can be of poor quality. A close and important relationship exists between the radiation dose and image quality. According to the “as low as reasonably achievable” (ALARA) principle, it is important for both patients and operators to reduce the radiation dose to the minimum level while maintaining sufficient image quality (Takeshita et al. 2017; Pauwels et al. 2014, 2015; Goulston et al. 2016; Kuramoto et al. 2021; ICRP 2007). Use of poor-quality images obtained with reduced radiation doses may lead to misdiagnosis. Regarding spatial resolution, CBCT is also superior to MDCT as the size of the FOV is smaller. A larger FOV of MDCT, including the whole head, decreases the spatial resolution and increases the scatter (Pauwels et al. 2021). Only hard tissues, i.e. bone and teeth, need to be evaluated, but not the surrounding soft tissues for the third molar extraction. Therefore, CBCT

Table 2.4 Characteristics of cone beam computed tomography (CBCT) versus multidetector computed tomography (MDCT)

	CBCT	MDCT
Radiation dose	Lower	Higher
Field of view	Smaller	Larger
Spatial resolution	Higher	Lower
Detectability of soft tissue	No	Yes
Quantitative value like CT value	No	Yes
Size of machine	Smaller	Larger
Cost	Lower	Higher

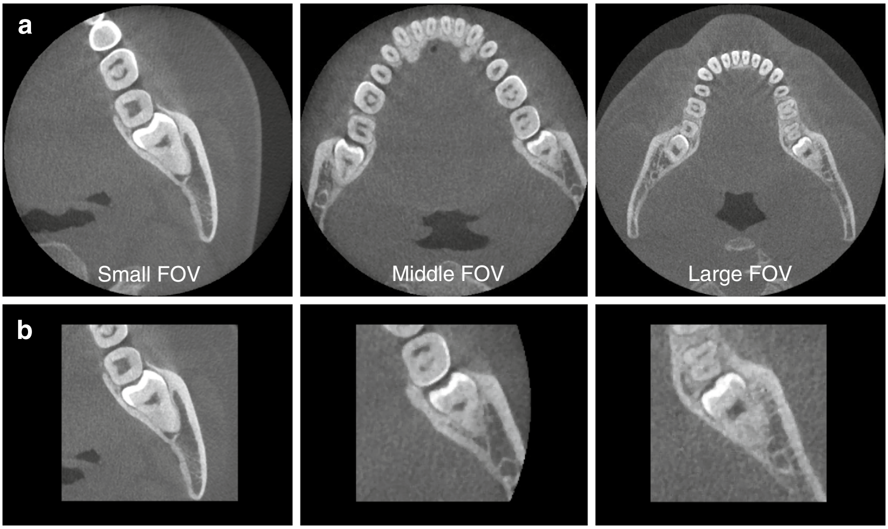


Fig. 2.4 Differences of the size of the field of view (FOV) and the spatial resolution on cone beam computed tomography (CBCT) images. (**a**) Examples of axial CBCT images including the mandibular third molar in different sizes of FOV. (**b**) The spatial resolution decreases as the size of the FOV is larger

should be chosen, not MDCT if applicable, if there are signs of a high risk of injury to the MC as suggested by preoperative panoramic images (Ghaeminia et al. 2011; Ghaeminia et al. 2015; Kursun et al. 2015; Roeder et al. 2012; Yabroudi and Sindet-Pedersen 2012; Tantanapornkul et al. 2007).

The number and the type of CBCT have increased not only in the hospital but in the private practice these days, as it is smaller size and lower cost compared with MDCT. All operators should understand the characteristics of CBCT and select the correct parameters (de Oliveira Pinto et al. 2020, 2021; Jones et al. 2015). The size of the FOV is a major determinant of the dose level and can vary. Therefore, it is important to choose appropriately for higher image quality. The CBCT shows various patterns: range is about from 40 mm × 40 mm to 200 mm × 200 mm (diameter × height).

A small FOV is suitable for a unilateral mandibular third molar, a medium-size FOV is suitable for bilateral mandibular third molars, and a large FOV is suitable for bilateral mandibular third molars of larger patients (Fig. 2.4a). It seems that medium and large sizes of FOV are easy and convenient to keep the target mandibular third molar within the field; however, this is not recommended. A larger FOV increases both the radiation dose and the scatter and decreases the spatial resolution. Regarding the spatial resolution, the number of pixels in the FOV is generally adjusted so that the size of pixels is smaller in a small FOV; in other words, the spatial resolution is greater in a smaller FOV (Fig. 2.4b). The tube voltage and tube current also should be adjusted, as needed, according to the patient, e.g. adult or child, male or female, etc.

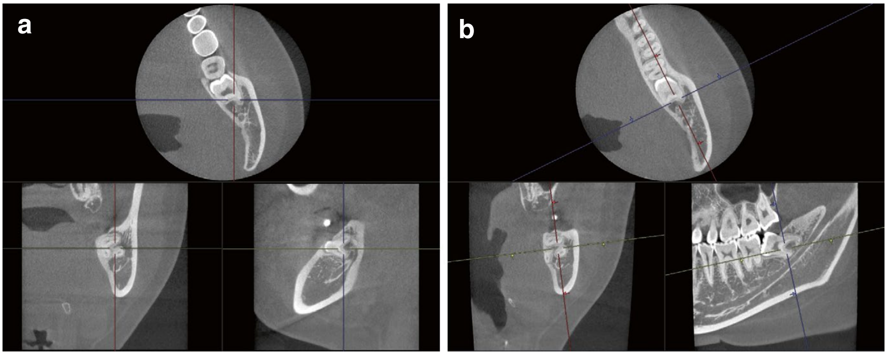


Fig. 2.5 A cone beam computed tomography (CBCT) image of the left mandibular third molar on CBCT viewer. (**a**) It is difficult to observe the relationship between the mandibular third molar and the mandibular canal without axis adjustment. (**b**) The relationship between the mandibular third molar and the mandibular canal can be observed clearly with the appropriate axis adjustment

Tips on Reconstructing the CBCT Images

The most significant factor for proper diagnosis is obtaining CBCT images appropriately and reconstructing them using the right method. Since only the axial images are saved as original images when scanning, the coronal and sagittal images are needed in order to reconstruct the axial images. However, the CBCT viewer is usually equipped with a reconstruction system; therefore, the operator only needs to adjust the axis of the object. In fact, this axis adjustment of the object is the most important part. Many operators tend to observe the displayed images as they are, but in fact, this is not recommended (Fig. 2.5a). The axis should be adjusted following the occlusal plane, the arch of the teeth (jawbone), and the objective tooth axis (Fig. 2.5b).

Positional Relationship of MC and Mandibular Third Molar on CBCT

The position and shape of the MC and relationship between the MC and the mandibular third molar differ among patients. The differences of the MC position (buccal, inferior, lingual, inter-radicular), shape (round/oval, teardrop, dumbbell), and contact (none, single, double) have been reported using CBCT images (Figs. 2.6, 2.7 and 2.8). Shujaat et al. (2014) reported that the root of the third molar was positioned buccal to the MC in most cases (74%) followed by middle (apex of root) (18%) and lingual (8%). According to Al Ali and Jaber (2020), the root of the third molar was positioned lingual, buccal, inferior, and inter-radicular to the MC in 45 (57%), 18 (22.8%), 14 (17.7%), and 2 (2.5%) cases, respectively. Impacted

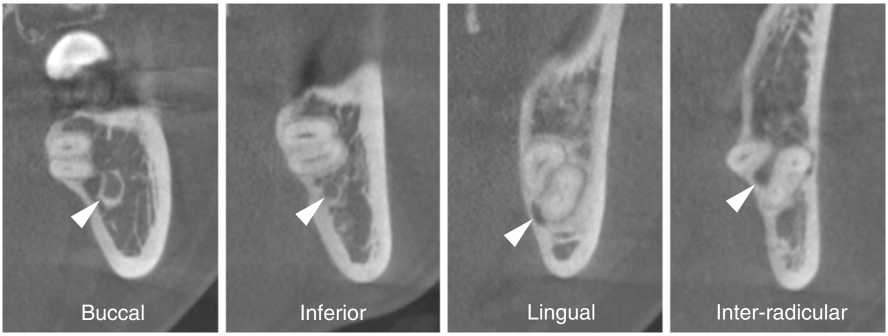


Fig. 2.6 Different position of the mandibular canal (arrow) to the mandibular third molar root

Fig. 2.7 Different shapes of the mandibular canal (dotted line) in the position of the mandibular third molar root

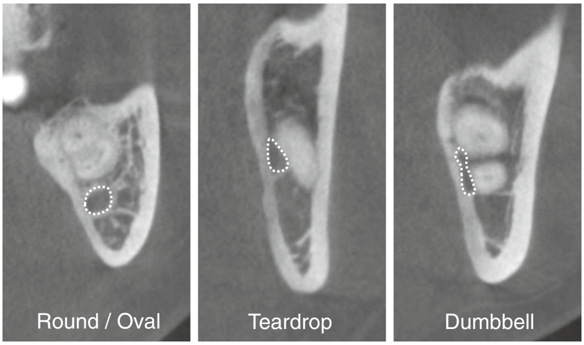
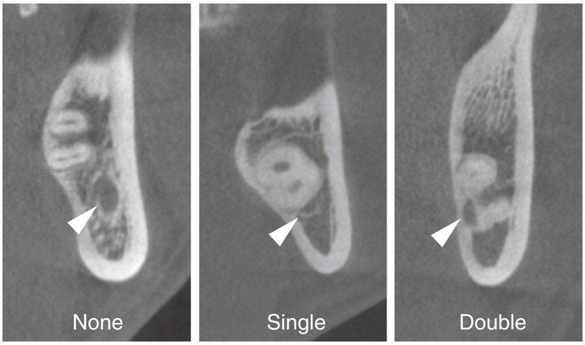


Fig. 2.8 Contact of the mandibular canal (arrow) with the mandibular third molar root



mandibular third molars tended to be positioned lingually (74%) without perforation of the lingual cortical plate in most patients. The bone around the third molars positioned lingually was more likely to be thinner than that around those positioned centrally and buccally (Khojastepour et al. 2019). Other studies reported that the most prevalent position of the root of the third molar was above the MC, followed by the lingual to the MC (Chen et al. 2018; Maglione et al. 2015; Quirino de Almeida Barros et al. 2018). Yabroudi and Sindet-Pedersen (2012) showed that most third

molars positioned superior and buccal to the MC. Thus, it is difficult to determine the tendency of the positional relationship between the root of the mandibular third molar and the MC as shown in these studies.

Detection of Anatomical Risk Factors

There were statistically significant differences for detecting anatomical risk factors between panoramic radiography and CBCT which provides a beneficial three-dimensional information of the relationship between mandibular third molar roots and the MC (Baqain et al. 2020). In the Winter classification, the "intersecting" relationship on CBCT appears more frequently in mesioangular third molars than in other angulations. In the Pell and Gregory classification, the frequency of an "intersecting" of the third molar decreased (class III), and the depth of impaction increased (Position C) (Khojastepour et al. 2019). The mandibular third molars positioned lingually were the most deeply impacted, followed by those positioned centrally and buccally (Ge et al. 2016). A dumbbell or teardrop-shaped MC usually shows direct contact with the root (Ueda et al. 2012). The incidence of an "intersecting" position of the root apex into the MC was higher than a mesioangular third molar (65.9%), which is the major type of impaction in the Winter classification (Khojastepour et al. 2019). In contrast, a buccal position of the mandibular third molar was more frequent in mesioangular types compared to other angulations (Khojastepour et al. 2019).

Treatment Planning

Assessment with panoramic images provides sufficient information for deciding whether or not to extract the whole tooth or to choose an alternative, for example, coronectomy. It has been argued that experienced surgeons can plan the surgical approach without CBCT images (Baqain et al. 2020). However, three-dimensional information from the CBCT images can drastically affect the choice of surgical approaches towards tooth extraction by revealing the buccolingual relationship between the MC and the mandibular third molar (Ghaeminia et al. 2011). This makes it possible for surgeons to decide, if they should remove buccal bone, where to place elevators, and if they need to remove extra bone after coronectomy. However, de Toledo et al. (2020) concluded in their systematic review that there is no strong evidence that CBCT reduces the risk of IAN injury following mandibular third molar surgery.

Overall Benefit of CBCT

CBCT provides clearer visualization of relevant anatomical structures than panoramic images, particularly the roots of the mandibular third molar and the mandibular canal (MC), offering operators additional information, including risk factors.

While the three-dimensional data from CBCT may not necessarily alter the surgical procedure or outcome, it can still be considered—especially by inexperienced surgeons—when panoramic images suggest a high risk of inferior alveolar nerve (IAN) injury.

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3 Epidemiology, Indications and Contraindications of Mandibular Third Molar Extraction

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Introduction

Removal of the mandibular third molar is one of the most common surgical procedures performed in oral and maxillofacial surgery (French Society of Stomatology and Maxillo-Facial Surgery and Oral Surgery 2020; Iwanaga et al. 2020). Surgical removal is used for various reasons, e.g. pericoronitis, dental caries, destruction of

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the adjacent tissues, odontogenic cysts, and tumours (de Bruyn et al. 2020; French Society of Stomatology and Maxillo-Facial Surgery and Oral Surgery 2020; Ghaeminia et al. 2016). This procedure has potential complications (De Bruyn et al. 2020). Therefore, all clinicians need to understand the indications and contraindications of mandibular third molar removal.

Indication of Mandibular Third Molar Extraction

To date, several position papers and guidelines have been published in several societies (*Agence nationale d'accréditation et d'évaluation en santé. Indications et non-indications de l'avulsion des troisièmes molaires mandibulaires* 1997; Agency for Quality in Dentistry 2006; American Association of Oral and Maxillofacial Surgeons 2016; French Society of Stomatology and Maxillo-Facial Surgery and Oral Surgery 2020; National Institute for Health and Care Excellence 2018). In 1997, the National Health Certification and Evaluation Agency (ANAES) published guidelines on the indications and contraindications of the mandibular third molar extraction (*Agence nationale d'accréditation et d'évaluation en santé. Indications et non-indications de l'avulsion des troisièmes molaires mandibulaires* 1997). The ANAES categorized risks of mandibular third molar extraction (Table 3.1). In the Agency for

Table 3.1 Risks of mandibular third molar extraction (ANEAS 1997)

	Risks of mandibular third molar extraction	
Expected immediate disability after extraction	Pain, suffering Loss of function Activity limitation Oedema Bruise Complications from anaesthesia	
Minor and temporary risks	Sensory nerve damage (sequelae less than 6 months) Dry socket 1–5% Infection and trismus 2–4% Haemorrhage 0.6–5.8% Dentoalveolar fracture Dental projection	1–6% 1–5% 2–4% 0.6–5.8% 2% Incidence not determined
Minor and permanent risks	Periodontal trauma to the neighbouring tooth Temporomandibular joint disorders Tooth error (extraction of another tooth) Secondary dental migration	0.3% Incidence not determined Incidence not determined Incidence not determined
Major risks	Permanent dysesthesia Infection of vital organs with bacteraemia Fracture of the mandible Injury	1% Incidence not determined Incidence not determined
Other risk	Disputes	

Table 3.2 Indication for mandibular third molar extraction (Agency for Quality in Dentistry 2006)

	Indication for mandibular third molar extraction	
	Recommendation A	Recommendation B
Symptomatic mandibular third molar	Acute or chronic infection (acute pericoronitis) Exposed pulp due to caries Non-restorable caries-damaged teeth or untreatable pulpitis Untreatable periapical changes Manifest pathological structures associated with dental follicles (e.g. cysts or a tumour) or suspicion of such changes Resorption of adjacent teeth In connection with the treatment of periodontal disease or limitation of its progression Where the tooth is to be used for transplant purposes	If it appears that the third molar is a significant source of pain Teeth that impede orthodontic and reconstructive surgery Teeth in the fracture gap that impede fracture treatment If the elongated or inclined third molar presents a manifest disturbance of dynamic occlusion
Asymptomatic mandibular third molar (having regard to the local risks of surgery)		Prophylactic extraction for higher-level reasons associated with the patient's life situation If other measures are being conducted under anaesthetic and further anaesthesia would be necessary for extraction of a third molar Where prosthetic treatment is planned and secondary eruption due to further atrophy of the alveolar ridge or to pressure of the removable prosthesis is likely To facilitate orthodontic treatment such as tooth movement and/or retention

Quality in Dentistry (2006), indications for mandibular third molar removal were enumerated, and their recommendation levels were divided into three, i.e. A strong recommendation, B recommendation, and O recommendation open (Table 3.2). The British National Institute for Health and Care Excellence (NICE) (*National Institute for Health and Care Excellence. Guidance on the extraction of wisdom teeth. Technology appraisal guidance* 2000) published "Guidance on the Extraction of Wisdom Teeth" in 2000. This was updated in 2014 (Table 3.3). They mentioned that the retention of the third molar might induce pathological changes such as pericoronitis, carious and peri-apical lesions, and orthodontic problems. The American Association of Oral and Maxillofacial Surgeons (AAOMS) had published a position statement on third molar management after collaborating with a large number of organizations (American Association of Oral and Maxillofacial Surgeons 2016).

Table 3.3 Indication for mandibular third molar extraction (NICE 2000)

Indication for mandibular third molar extraction	
Symptomatic unerupted mandibular third molar	Asymptomatic mandibular third molar
Deep, non-treatable carious lesions Non-treatable pulpal or periapical pathology Cellulitis, abscess, and osteomyelitis Fracture of tooth Resorption of the tooth or adjacent tooth Osteolytic illness (including cysts and tumours) Tooth impeding surgery or jaw reconstruction Tooth involved in/within the field of tumour resection Recurring pericoronitis (excluding a single occurrence)	Not recommended as patients may be uselessly exposed to surgery-related risks (i.e. temporary or permanent nerve lesion, alveolar osteitis, infection, haemorrhage, local risks of inflammation, pain, and trismus)

Mandibular third molar extraction is indicated when there is pathology or a high risk of developing disease. The AAOMS Position Statement said that the removal of asymptomatic mandibular third molar could be selected in the following situations: when the mandibular third molar is currently or might be in the future non-functional, when there is a removable prosthesis overlying the teeth, when orthodontic removal is justified such as preventing the second molar eruption, and when a patient has planned orthognathic surgery (American Association of Oral and Maxillofacial Surgeons 2016). Mandibular third molar extraction or retention should be decided by the middle 30s considering the potential risk predicated on the clinical situation (American Association of Oral and Maxillofacial Surgeons 2016). Patients should be informed that the difficulty and complications in third molar extraction increase with age (American Association of Oral and Maxillofacial Surgeons 2016). If the patient decides to retain the third molar, active surveillance by the dentist is essential in order to discover pathological changes as quickly as possible (American Association of Oral and Maxillofacial Surgeons 2016). All these guidelines recommend removing the symptomatic pathological tooth, while management with an asymptomatic tooth has not reached a consensus (French Society of Stomatology and Maxillo-Facial Surgery and Oral Surgery 2020). The French have suggested a decision table for the extraction of the mandibular third molar based on existing guidelines (Table 3.4).

Table 3.4 This decision table is based on existing guidelines including French good practice guidelines of mandibular third molar extraction (Edited by Iwanaga et al. 2020) M3, mandibular third molar

	Indication for mandibular third molar extraction	
	Pathological	Nonpathological
Symptomatic M3	Mandibular third molar symptomatic caries with no long-term restoration prognosis Nontreatable symptomatic pulp/periapical pathology (granuloma, cyst) M3-related cellulitis, abscess, osteomyelitis M3-related periodontopathy M3 symptomatic fracture	Recurrent or conservative treatment -resistant pericoronitis Internal/external resorption of adjacent tooth M3 altering dynamic occlusion
Asymptomatic M3	Mandibular third molar asymptomatic caries with no long-term restoration prognosis Nontreatable asymptomatic pulp/periapical pathology (granuloma, cyst) M3 asymptomatic fracture M3 associated with a cyst or malignant tumour M3 associated with a possibly malignant pathology M3 positioned in line of bony fracture (reduction and optimization of osteosynthesis)	Anticipation of difficulties or potential complications associated with M3 root development and likely proximity with alveolar nerve Health condition: Incoming radiotherapy, potential diabetes, heart condition, and/or immunosuppressant-related infection area M3 positioned in surgical field and/or jaw reconstruction Transplanted M3 Placement of an implant near a nonerupted M3 Assessment of specific, inappropriate life condition in order to prevent M3-related troubles [pregnancy, physical/emotional stress, (air) travel, sports activity, military deployment, etc.] Prevention of resorption of adjacent tooth crown or root Nonfunctional M3 (no antagonist, with risk of elongation) Optimization/planning of a prosthesis: Likeliness of secondary eruption or impacted tooth in a tissue-borne prosthesis area Evaluation of orthognathic surgery in case of surgical difficulty (M3 an obstacle to osteotomy) Orthodontic need if an easier distal displacement second molar

Special Considerations

Relationship Between the Second and Third Molars

McArdle and Renton (2006) reviewed 100 patients (122 sides) who underwent extraction of the mandibular third molar due to distal cervical caries in the second molar. The average age of all patients was 30 years (range 18 to 64 years), although



Fig. 3.1 Panoramic and periapical radiography showing a large distal cervical caries of the mandibular second molar and the mesially angulated impacted mandibular third molar

other studies have found this average age range between 25 and 28 years (Chiapasco et al. 1993; Lysell and Rohlin 1988; McArdle and Renton 2006; Nordenram et al. 1987). Some authors have suggested that patients with good oral hygiene were less susceptible to pericoronitis with the mandibular third molar but had a potential risk of caries in the distal neck of the second molars due to long-term plaque accumulation. Dental caries develop slowly. Therefore, the patients in this study were older than the average age of patients undergoing mandibular third molar removal in other studies. They recommend that a partially erupted mesioangular mandibular third molar should be removed early and prophylactically to prevent distal cervical caries in the second molar (McArdle and Renton 2006) (Fig. 3.1).

In 2016, a systematic review with regard to surgical removal versus retention for asymptomatic mandibular third molar was published by the Cochrane Collaboration, which is based on the results of a prospective cohort study conducted by Nunn et al. (Ghaeminia et al. 2016; Nunn et al. 2013). This review focused on the risk of periodontitis and caries of the second molar by removal or retention of the adjacent mandibular third molar. Absence of the mandibular third molar slightly reduced the risk of periodontitis of the distal part of the second molar and radicular resorption of a second molar compared with the presence of asymptomatic submucosal mandibular third molar. Alternatively, the absence of a mandibular third molar did not reduce the risk compared with the presence of asymptomatic bony impacted mandibular third molar. Regarding the risk of caries, there was no significant difference in the prevalence of distal caries in the second molar with a submucosal or bony impacted mandibular third molar, whereas there was a significantly increased risk of distal caries on the second molar in cases of a fully erupted mandibular third molar.

Petsos et al. (2016) assessed the impact on the periodontal health of the adjacent second molar following the removal of asymptomatic impacted mandibular third molars for young patients. They demonstrated that the clinical parameters, e.g. probing pocket depths and attachment levels, improved significantly 6 months after removing the mandibular third molar. They also analysed whether or not there was

any change in pocket depths and attachment levels relating to each type of impaction which is submucosal (fully covered by oral mucosa) or impacted (entirely within the bone). As a result, there was no statistically significant difference of the attachment levels between each type of impaction, but the pocket depths were reduced 0.4 mm more in submucosal than in impacted mandibular third molars. They concluded that mandibular third molar extraction for younger patients might be beneficial for their periodontal tissues of the adjacent second molars.

Qu et al. (2017) showed in their cross-sectional study that the presence of a visible mandibular third molar increased the pathological parameters of periodontitis such as the plaque index, bleeding on probing, and probing the pocket depth of the adjacent second molar. They concluded that the presence of the mandibular third molars, including a normal eruption, whether symptomatic or asymptomatic, may exacerbate periodontal health of the adjacent mandibular second molar. They recommend removing the mandibular third molar as soon as possible with or without disease for a reduction in complications and periodontal health of the adjacent mandibular second molars.

Wang et al. (2017) analysed the risk of external root resorption of the second molar adjacent to a mesial and horizontal impacted mandibular third molar in a retrospective study using cone beam computed tomography (CBCT). The incidence of external root resorption was found in 20.17% (73/362) and increased with age. In the Pell and Gregory classification (Pell and Gregory 1933), class A and C had a higher incidence of external root resorption than class B. External root resorption in an adjacent second molar is not a rare clinical condition, and clinicians can identify it using CBCT image. Therefore, they recommended the prophylactic removal for a patient over 35 years old with a mesial and horizontal impacted mandibular third molar.

Association with the Occurrence of Mandibular Fracture and Mandibular Third Molar Removal

Xu et al. (2017) have conducted a systematic review including 13 retrospective cohort studies to clarify the association of the mandibular third molar with mandibular angle and mandibular condylar fractures. As a result, the presence of mandibular third molars increased the risk of mandibular angle fractures and decreased the risk of mandibular condylar fracture. The presence of the mandibular third molar results in reducing the quantity of bone because of occupying more space in the mandible and makes the bony strength weak (Naghipur et al. 2014) (Figs. 3.2 and 3.3). Thus, a patient with the mandibular third molar is more likely to have a fracture at the mandibular angle, which was demonstrated in the animal study of Reitzik et al. (1978). Many studies have reported the association of the mandibular third molar position or angulation with mandibular angle fracture, but the results have been inconsistent (Xu et al. 2017). Xu et al. (2017) have reviewed the risk of condylar fracture in patients with the mandibular third molar and found that it was 0.47 times that in patients without it. The absence of an unerupted mandibular third

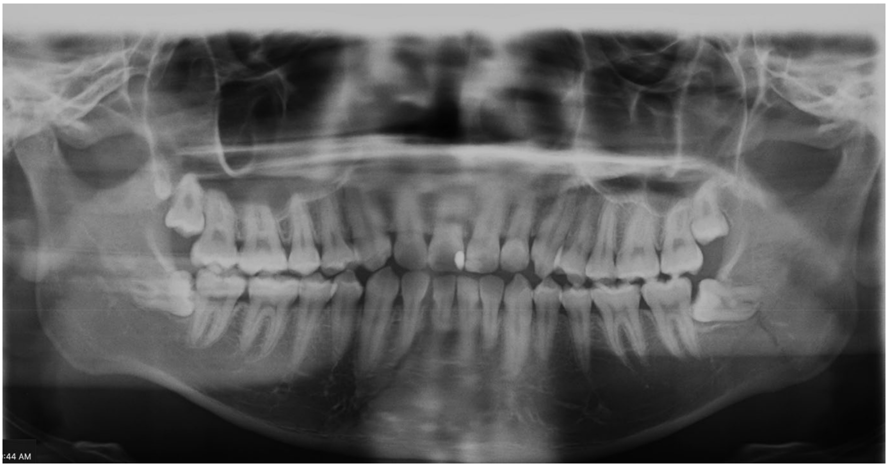


Fig. 3.2 Panoramic image of a left mandibular angle fracture with a horizontal impacted mandibular third molar

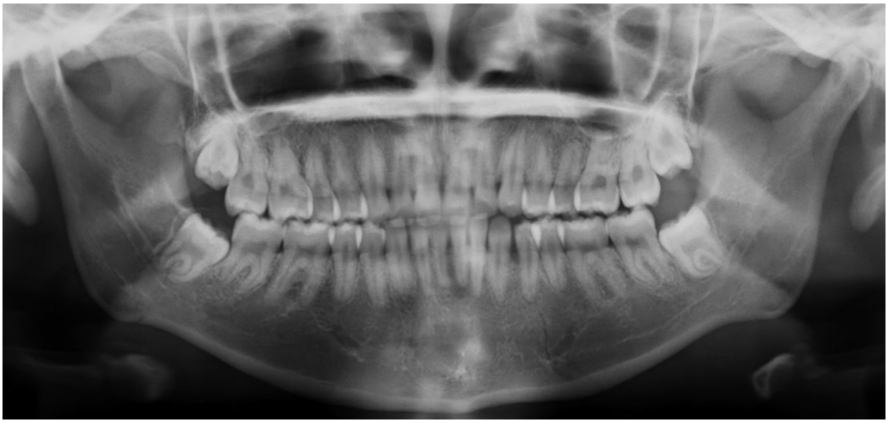


Fig. 3.3 Panoramic image of a right mandibular angle fracture with a mesioangular impacted mandibular third molar

molar might increase the prevalence of mandibular condylar fractures (Xu et al. 2017). Based on their results, Xu et al. (2017) suggested that all clinicians should carefully make a decision for removing the mandibular third molar realizing the increased risk of mandibular angle and condylar fractures (Xu et al. 2017). In contrast, Sukegawa et al. (2019) have demonstrated, using a retrospective cohort study, that occlusal support and the presence of the mandibular third molar significantly increased the risk of subcondylar fractures. These differences might have resulted in condylar fractures being subdivided into subcondylar and condylar head fractures.

Contraindications of Mandibular Third Molar Removal

There is the absence of clear evidence or consensus statements regarding retaining asymptomatic mandibular third molars. The most common reason for retaining the mandibular third molar is advanced age as surgical removal of mandibular third molars becomes more complex and has more risk of complications as the patient's age increases (Berge and Bøe 1994). Advanced age results in the periodontal ligament becoming thinner, tooth ankylosis, prolongation of recovery from complications, and incomplete recovery (De Bruyn et al. 2020; Pogrel 2012). Moreover, the bone becomes densely calcified, and it is less flexible and less likely to bend under the forces of tooth extraction (Bruce et al. 1980). It has been clarified that the complication rate in older patients over 25 years old was 1.5- to 3.0-fold higher than in younger patients under 25 years old (Chiapasco et al. 1993; Chuang et al. 2007).

In the Agency for Quality in Dentistry (2006), contraindications for clinically and radiologically asymptomatic third molars were enumerated as follows:

(i) Where spontaneous regular tooth positioning of the third molars in the dental arch is suitable. Grade A.
(ii) If removal of other teeth and/or orthodontic treatment with correct tooth positioning is appropriate. Grade A.
(iii) Profoundly impacted and malpositioned teeth without pathological condition, where a high risk of surgical complications exists. Grade B.

Each grade is based on the level of scientific evidence and grading of guidelines. Grade A represents established scientific evidence, i.e. high-power randomized comparative studies, a meta-analysis of randomized comparative studies, and decision analysis based on well-conducted studies. Grade B represents scientific presumption, i.e. low-power and randomized comparative studies; well-conducted, non-randomized comparative studies; and cohort studies. The Finnish Current Care Guidelines for the third molar (2014) has stated that asymptomatic tooth extraction should not be applied in the following cases:

(i) Asymptomatic, pathology-free impacted tooth.
(ii) Local or general risk: nerve lesion, jaw fracture, previous radiotherapy at the level of the jaw, immunodepression, and immunosuppressive therapy.
(iii) It is determined on a case-by-case basis.

Ventä (2015) stated that there are only two contraindications to third molar removal: (1) an unerupted, disease-free, asymptomatic third molar completely covered with bone and (2) when third molar removal constitutes an unreasonable risk to the general or local health of the patient. The AAOMS Position Statement (2016) advocated that third molar removal should not be performed in the following cases:

(i) A third molar in normal position in the tooth arch and is functional, asymptomatic, free of caries, without periodontitis.

(ii) An impacted third molar with complete root formation in a patient over 30 years old with no pathological condition.

Active clinical and X-ray surveillance is needed as the future of patients with asymptomatic, disease-free third molars cannot be confidently predicted. All clinicians, based on their own experience and expertise, need to communicate the potential for pathological conditions to patients appropriately. Patients have the right to know that they might be able to spend their whole lives without problems with a disease-free and asymptomatic third molar. De Bruyn et al. (2020) identified and quantified contraindications to remove third molars and other reasons to retain third molars in their retrospective cohort study. They classified contraindications for third molar removal (reasons to retain third molars) into eight categories.

(i) Potential risk of damaging adjacent structures.
(ii) Compromised health status.
(iii) Enough space for the eruption.
(iv) Functions as an abutment tooth.
(v) Orthodontic reasons.
(vi) Normal eruption.
(vii) Asymptomatic third molars over 30 years old.
(viii) Patient rejection.

The most common reasons for retaining mandibular third molars were normal eruption (not impacted) (37.5%) followed by patient rejection (29.3%), asymptomatic mandibular third molars over 30 years old (14.2%), and the potential risk of damaging adjacent structures (10.1%) (Table 3.5). Compromised health status was subcategorized into bleeding disorders, intravenous antiresorptive agents (e.g. bisphosphonates or denosumab), chemo- and/or radiotherapy patients, immunocompromised patients, pregnancy, and other severe health problems. Especially, a compromised health status and advanced age have a close relationship and affect the decision of whether or not to remove the third molars. Also, there are cost/economic considerations as other reasons to retain third molars. The cost problem might be an essential factor in countries without inclusive social insurance systems. Dentists,

Table 3.5 Reasons for retaining mandibular third molars (Bruyn et al. 2020)

Contraindications for mandibular third molar extraction	
Contraindications	Mandibular third molar n (%) (total 299 sides)
(i) Potential risk of damaging adjacent structures	70 (10.1%)
(ii) compromised health status	29 (4.2%)
(iii) enough space for the eruption	15 (2.2%)
(iv) functions as an abutment tooth	5 (0.7%)
(v) Orthodontic reasons	13 (1.9%)
(vi) eruption into appropriate occlusion	261 (37.5%)
(vii) asymptomatic third molars over 30 years old	99 (14.2%)
(viii) patient rejection	204 (29.3%)

including oral surgeons, who treat patients with mandibular third molar, need to determine if the patients should undergo surgery based on the aforementioned status/background of the patients and the condition of the tooth.

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4 Mandibular Third Molar Extraction and the Patient's Medical History

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Introduction

Extraction of the mandibular third molar is generally performed for the relatively younger generation. Occasionally, the elderly patients require the extraction of the third molar for prevention of the oral infection such as preoperative management of the fracture treatment. The prevalence of systemic disease can increase with aging so the elderly patient perioperative management would be more complicated. The patient's medical history and degree of invasion need to be considered.

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Cardiovascular Disease

Hypertension

According to a 2013 survey of the World Health Organization (WHO), more than one billion people over the age of 25 years were diagnosed with hypertension as of 2008. In other words, one in three over the age of 25 years has developed hypertension (World Health Day 2013). Hypertension is classified into essential hypertension of unknown causes and secondary hypertension caused by renal or endocrine diseases. Most individuals have essential hypertension, with blood pressures rising as they age. Even with no history of hypertension, anxiety towards tooth extraction and pain during treatment stimulates the sympathetic system, resulting in constriction of the peripheral blood vessels, increased cardiac output, and a sharp rise in blood pressure. Therefore, it is necessary to confirm the vital signs prior to surgery, establish a referral system that can immediately respond to emergency, and not to cause an increase in blood pressure by anxiety and stress (Ohki and Shigei 2013). Sufficient consent and anaesthesia can decrease anxiety. If the third molar extraction requires significant time and invasion such as osteotomy, intravenous sedation should also be considered. Furthermore, if the blood pressure is poorly controlled, the risk of postoperative bleeding increases.

The definition of the hypertension can be slightly different in regions and has changed frequently. European guidelines in 2018 defined hypertension as 140 and/or 90 mmHg (Williams et al. 2018). According to Japanese guidelines published in 2019, hypertension for adults was defined as 140 and/or 90 mmHg in the hospital and 135 and/or 85 mmHg at home (Japanese Society of Hypertension Treatment Guidelines 2019) (Table 4.1), although US guidelines in 2017 used 130 or 80 mmHg (Whelton et al. 2017).

According to the "Statement on the Use of Adrenaline-containing Local Anesthesia for Hypertensive Patients" issued by the Japanese Dental Society of Anesthesiology in 2019, adverse events may occur due to adrenaline in hypertensive patients, with the initial dose of 1/80,000 adrenaline-containing local anaesthetic stated as needing to be administered via up to two 1.8 ml cartridges as a guide. It is also recommended that patients with grade III hypertension (≧180 and/or ≧110) to physicians should be prioritized, except for emergency treatment, and that

Table 4.1 Classification of hypertension (Japanese Society of Hypertension Treatment Guidelines 2019)

	Systolic blood pressure		Diastolic blood pressure
Normal	<120	and	<80
Normal high blood pressure	120–129	and	<80
High blood pressure	130–139	or/and	80–89
Hypertension of grade I	140–159	or/and	90–99
Hypertension of grade II	160–179	or/and	100–109
Hypertension of grade III	≧180	or/and	≧110

(mmHg)

treatment should be discontinued if grade III hypertension occurs during treatment. Treatments should be scheduled in the morning, if possible, as diurnal fluctuations in blood pressure are often more stable in the morning.

Valvular Heart Disease

Valvular heart disease is a condition in which the valvular membrane does not function properly, due to stenosis or insufficiency of the valve and mainly includes atrial fibrillation, thromboembolism, cardiac arrest, and infective endocarditis. The number of operations for valvular heart disease has been increasing in recent years. The treatments include valvuloplasty or valve replacement (biological or mechanical valve). The patients who have a mechanical valve are required to take anticoagulants for the rest of their lives, and the patients with biological valves for 3 to 6 months, postoperatively (JCS et al. 2020). Transcatheter aortic valve implantation (TAVI) was approved for aortic valve stenosis in 2013. This is a treatment in which an artificial valve is inserted via the femoral artery using a catheter and is used to replace the native aortic valve. In addition, percutaneous transluminal mitral commissurotomy (PTMC) for mitral valve stenosis and percutaneous mitral valve insufficiency repair (MitraClip) for mitral regurgitation are also performed.

The prevention of infective endocarditis (IE) is of paramount importance in the dental treatment of patients with valvular heart disease. The 2007 American Heart Association (AHA) guidelines recommend antibiotic prophylaxis for patients with prosthetic valve replacement and patients with a history of endocarditis (Table 4.2). According to Heimdahl et al. (1990), the incidence of bloodstream infection during tooth extraction is 55%. Therefore, antibacterial agents should be administered prophylactically in line with the above guidelines when tooth extraction is performed.

Tooth extractions in patients receiving antithrombotic drugs should be performed without discontinuing the antithrombotic drug in accordance with the 2009 guidelines for anticoagulant and antiplatelet therapy for cardiovascular disease. Although no clear consensus has been reached for tooth extraction in patients taking newer anticoagulants (NOAC), tooth extraction under the continuous use of these drugs is

Table 4.2 Preoperative antibiotic administration in 2007 AHA guidelines

Administration method	Antibacterial drug	Adult	Child
Oral administration	Amoxicillin	2 g	50 mg/kg
Non-oral administration	Ampicillin Cefazolin Ceftriaxone	2 g IM or IV 1 g IM or IV 1 g IM or IV	50 mg/kg IM or IV 50 mg/kg IM or IV 50 mg/kg IM or IV
Penicillin contraindications, oral administration	Cefalexin Clindamycin Azithromycin Clarithromycin	2 g 600 mg 500 mg 500 mg	50 mg/kg 20 mg/kg 15 mg/kg 15 mg/kg
Penicillin contraindications, non-oral administration	Cefazolin Ceftriaxone Clindamycin	1 g IM or IV 600 mg IM or IV 600 mg IM or IV	50 mg/kg IM or IV 20 mg/kg IM or IV 20 mg/kg IM or IV

generally accepted. The points differing from the conventional antithrombotic therapy are that it has a short half-life in the blood and some drugs are taken twice a day. Therefore, when extracting teeth, it is recommended that the time when the blood concentration increases should be avoided and surgery should be performed 6 hours (12 hours if possible) after taking the drug.

Taking into consideration that a bleeding tendency is involved with the procedure, we should attempt to completely close the wound with a minimal gingival incision and osteotomy. Because it is difficult to close the wound completely after extraction of the erupted wisdom tooth, a local haemostatic agent such as cellulose oxide cotton or gelatin sponge may be inserted into the extraction socket to perform pressure haemostasis; alternatively, a haemostatic plate should be prepared prior to surgery which is worn until complete haemostasis is confirmed.

Respiratory Disease

Bronchial Asthma

Bronchial asthma is a chronic inflammatory disease of the airway. The morbidity associated with this disease is reportedly 14% in children and 8.6% in young adults. Chronic inflammation increases airway hyper-responsiveness, with various stimuli narrowing the airway lumen, causing symptoms such as wheezing, shortness of breath, and chest tightness. The cause of onset includes genetic predisposition as an individual factor and allergens such as mites as an environmental factor, with approximately half of patients being atopic. Treatments include anti-inflammatory therapy (the use of inhaled corticosteroids) aimed at preventing attacks and steroid therapy during acute exacerbations (increased dose of inhaled corticosteroids and administration of oral corticosteroids). Severe asthma attacks may occur after taking acidic non-steroidal anti-inflammatory drugs (NSAIDs) such as aspirin, referred to as aspirin-induced asthma (AIA). It should be noted that when NSAIDs are used in AIA patients, asthma attacks occur within approximately 2 hours, with such attacks occasionally being so severe that they cause a disturbance of consciousness, quite often resulting in death.

Therefore, when performing third molar extraction, we should make sure to check the patient's history for asthma. We also ask patients to bring their inhalants when undergoing treatment and ask them to use it once before the procedure. Acetaminophen, NSAIDs, and pentazocine are the first choices for pain management in AIA patients. Komi et al. reported good post-extraction pain management in AIA patients, using tramadol hydrochloride/acetaminophen combination tablets (product name, Tramset). Gopalraju et al. (2014) also reported that intravenous administration of 50 mg of tramadol hydrochloride was effective in 85% of cases of pain after the extraction of horizontally impacted mandibular third molars. In particular, NSAIDs and low-dose acetaminophen often do not provide a sufficient analgesic effect following the extraction of impacted third molars with osteotomy. Therefore, it is better to select an analgesic in accordance with each

specific case. If the patient is taking steroids as a treatment for asthma, the necessity of steroid cover will be examined according to the dose and duration of administration.

Gastrointestinal Disorders

While NSAIDs are often selected as the first choice for post-extraction analgesics, the development of gastrointestinal ulcers has been reported as a drawback of NSAIDs. The use of NSAIDs is contraindicated in patients with acute gastric mucosal lesions and gastric/duodenal ulcers, so careful administration is required for patients with a history of gastric ulcers. Sakamoto et al. (2013) reported that a 2-week-long oral administration of NSAIDs resulted in a 27.6% incidence of upper gastrointestinal ulcers in a double-blinded comparative study among healthy adults. Although a long-term oral administration of analgesics is not necessary, anti-ulcer drugs such as proton pump inhibitors and prostaglandin preparations might be used in combination if inevitably used for patients with a history of digestive disorders. Celecoxib is an anti-inflammatory analgesic that has less gastrointestinal complications because it selectively inhibits COX-2 while exhibiting the same anti-inflammatory and analgesic effects as NSAIDs (Fig. 4.1) (Kimoto et al. 2008). Celecoxib for post-extraction pain was reported to be effective in 88.0% patients, thus making it a suitable drug for patients with gastrointestinal ulcers.

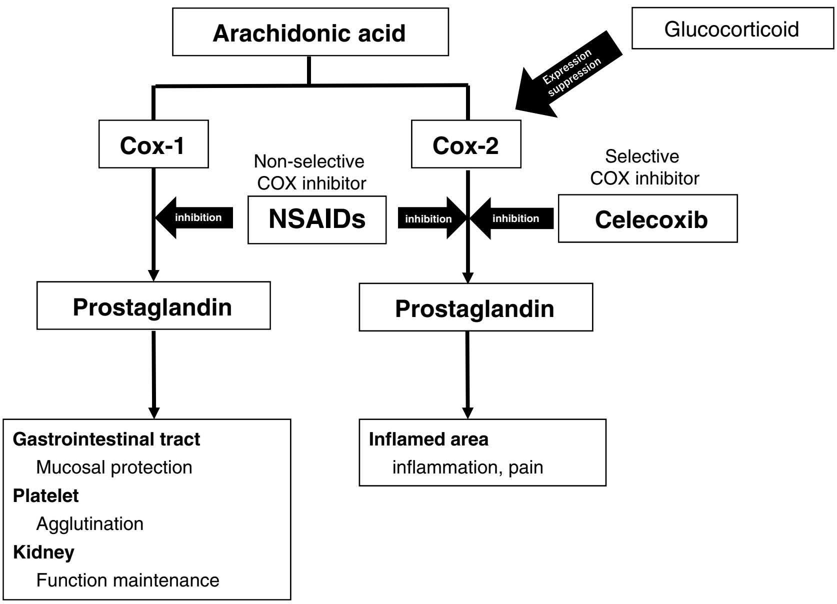


Fig. 4.1 Action mechanism of celecoxib and NSAIDs

Endocrine Diseases

Diabetes

This is a group of metabolic diseases in which the main characteristic is chronic hyperglycaemia due to insufficient insulin action, with genetic factors and environmental factors involved in the onset thereof. Prolonged metabolic abnormalities cause various complications (renal disorders due to diabetic nephropathy, hypertension, abnormal bone metabolism, etc.). Therefore, the points to be noted when extracting third molars are the following: 1. susceptibility to infections, 2. hypoglycaemic attack, and 3. presence or absence of complications.

1. Susceptibility to infections.

   A decrease in oxygen supply to the tissues occurs due to a decrease in the function of neutrophils and angiopathy, in association with a decrease in the function of the infection defence mechanism due to metabolic abnormalities. When an infection occurs, the metabolic mechanism is further disturbed, thus causing an aggravation of diabetes and ketoacidosis, resulting in a vicious cycle.

2. Hypoglycaemic attack.

   Hypoglycaemic symptoms may appear during dental treatment in patients who do not have sufficient food intake due to pain in the oral cavity. As a major premise of avoiding dental treatment on an empty stomach, if a hypoglycaemic attack occurs, let the patient immediately ingest a sugar-containing substance, and if ingestion is difficult, give an intravenous injection of 20 mg of 50% glucose.

3. Presence or absence of complications.

   Insulin functions to lower blood sugar levels in addition to acting on osteoblasts to promote bone formation. Insulin deficiency in type I diabetic patients suppresses the culturing and maturation of osteoblasts, leading to decreased bone formation and leaving them prone to developing osteoporosis. A systematic review of a cohort study reported that elderly diabetic patients suffered from a deterioration in bone quality and were associated with a risk of fracture seven-fold higher in type I diabetic patients and 1.5- to two-fold higher in type II diabetic patients compared to healthy subjects (Janghorbani et al. 2007). Bisphosphonate (BP) drugs are often used for diabetic osteopenia, so attention must be paid when extracting teeth (discussed later).

   NGSP (National Glycohemoglobin Standardization Program) is used as an index of blood glucose control, with less than 7.0% being the control target value (fasting blood glucose, less than 130 mg/dl; postprandial blood glucose level, less than 180 mg/dl) (Randie 2003). When performing an invasive treatment, except for emergency surgery, NGSP less than 6.9%, fasting blood glucose 100 to 140 mg/dl, or postprandial blood glucose 160 to 200 mg/dl should be used as a guide. If there is no choice but to extract teeth under poor control, it is necessary to thoroughly perform the preventive administration of antibacterial agents prior to and during surgery, because it will be an extraction in a state in which there is a high risk of surgical site infection (SSI). On the other hand, controlled diabetic patients have the same risk of SSI as healthy individuals, thus rendering it unnecessary to have preoperative prophylaxis.

Table 4.3 Thyroid-related hormones and standard values

Clinical test item		Standard values
Free Thyroid 3 (FT3)	Thyroid hormone	2.2–4.3 (pq/mL)
Free Thyroid 4 (FT4)	Thyroid hormone	0.8–1.6 (ng/dL)
Thyroid stimulating hormone (TSH)	Thyroid stimulating hormone	0.2–4.5 (μIU/mL)

Hyperthyroidism

This is a pathological disorder caused by excessive thyroid hormone secretion, including Graves' disease (Basedow's disease) and TSH-producing pituitary tumours, in which the function of the thyroid gland itself is enhanced, along with silent thyroiditis and subacute thyroiditis caused by a destructive mechanism. There are two symptoms: an increase in the basal metabolism associated with an excess of thyroid hormone and an increase in sympathetic nerve function. In particular, it should be noted that surgical invasion may exacerbate hyperthyroidism, leading to the development of a crisis, for situations in which thyroid function is not normal. In addition, local anaesthesia of epinephrine, which has a sympathomimetic effect in the state of hyperthyroidism, may further exacerbate hyperthyroidism. Furthermore, we should refrain from using lidocaine because it can cause tachycardia and arrhythmias. If the thyroid function is normally controlled (FT3, FT4, and TSH are within the normal range), local anaesthetic injection and surgical tooth extraction can be performed as usual (Table 4.3) (Ida et al. 2003).

Therefore, it is necessary to know the status of the patient's thyroid function in order to make sure that adrenaline is not used in the local anaesthetics.

Osteoporosis

This is caused by a decrease in bone formation ability due to aging along with a deficiency of oestrogen, the female hormone. Bisphosphonates (BP) and denosumab, which are bone resorption inhibitors, are recommended as the first-line treatment for osteoporosis.

In 2003, Marx (2003) reported necrosis of the jawbone as a side effect in patients treated with BP preparation, leading to it becoming known as bisphosphonate-related osteonecrosis of the jaw (BRONJ). Subsequently, Taylor et al. reported that jawbone necrosis also occurred in patients receiving denosumab, which is a complete human RANKLE (Receptor Activator of NF-kB Ligand) antibody drug, and currently, jawbone necrosis caused by either a BP preparation or denosumab is collectively called antiresorptive agent-related ONJ (ARONJ) or medication-related ONJ (MRONJ). Approximately half of the patients using bone resorption inhibitors are osteoporosis patients.

A position paper published in 2016 reported that the incidence of BRONJ in osteoporotic patients undergoing BP treatment was 0.001 to 0.01%. It is considered to be closely associated with the onset of ARONJ, because it is in an environment

that is extremely susceptible to infections compared to bones in other parts of the body. Invasive dental treatment is one of the risk factors of onset, with tooth extraction accounting for 67% of the triggers for the onset of ARONJ. In the case of dental treatment involving bone invasion, it is advised to complete it at least 2 weeks prior to initiating bone resorption inhibitor treatment. Regarding invasive dental treatment during administration of the BP preparation, there is no basis for actively instructing BP withdrawal (Umeda 2020). When treatment is required, it is recommended that antibacterial agents are preoperatively administered in order to minimize the degree and extent of invasion, the sharp edges of the bone remaining after treatment need to be smoothed, and the wound needs to be closed by the oral mucosa including the periosteum. The "Japanese clinical practical guidelines for antimicrobial prophylaxis in surgery" proposed in 2016 are applied for the preventive administration of antibacterial agents, with 250 mg of amoxicillin administered 1 hour before tooth extraction, and administration after tooth extraction should be judged from the invasion of tooth extraction and the ability to protect the patient from infections.

Blood Diseases

Leukaemia and Malignant Lymphoma

Hematopoietic cell transplant is often performed for haematological malignancies such as leukaemia and malignant lymphoma. It is classified into autologous transplantation, in which the patient's own hematopoietic stem cells are transplanted, and allogeneic transplantation, in which the donor's hematopoietic stem cells are transplanted. Approximately 1 week before hematopoietic stem transplantation, the patient's immunity is suppressed using a large amount of anticancer drug and total body irradiation, in order to promote the engraftment of transplanted cells and antitumor effect. During the period from pre-implantation treatment to neutrophil engraftment, dental infections are more likely to occur because cytopenia and oral mucositis render it more susceptible to infections. In other words, if there is a past history of pericoronitis or caries or incomplete eruption, it is desirable to complete the tooth extraction at least 2 weeks prior to transplantation (Futatsuki et al. 2002).

Kidney Disease

Chronic kidney disease (CKD) is diagnosed when renal disorders such as a decreased renal function persist for more than 3 months. Patients with CKD are at increased risk of needing dialysis in the future. According to Evidence-based Clinical Practice Guideline for CKD (2018), the severity of CKD is evaluated by the combined stage of primary disease, GFR classification, and proteinuria classification (Table 4.4).

Table 4.4 Severity of chronic kidney disease (CKD)

Primary disease	Proteinuria classification	A1	A2	A3
Diabetes	Urine albumin quantification (mg/day) Ratio of urinary albumin to creatinine (mg/gCr)	Less than 30	30–299	More than 300
Hypertension Nephritis Polycystic kidney disease Transplanted kidney Unknown Other	Urine protein quantification (g/day) Ratio of urinary protein to creatinine (g/gCr)	Less than 0.15	0.15–0.49	More than 0.50
GFR classification ($mL/min/1.73\ m^2$)	G1 normal or high (≧90)			
	G2 normal or mild decline (60–89)			
	G3a mild to moderate decline (45–59)			
	G3b moderate to highly lowered (30–44)			
	G4 highly lowered (15–29)			
	G5 end-stage renal failure (<15)			

Haemodialysis is performed 3 days a week. The following four points should be noted in dialysis patients:

1. Susceptibility to infections.

Uraemic substances in the blood inhibit the functions of granulocytes and lymphocytes, resulting in decreased immunity and susceptibility to infections.

2. Bleeding tendency.

Uraemic substances in the blood reduce platelet function. Heparin is administered to prevent blood coagulation in the circuit, so patients undergoing haemodialysis often suffer from cardiovascular disease and are taking anticoagulants or antiplatelet drugs.

3. Hypertension and dialysis-related hypotension.

Drug control is not easy for renal hypertension, and blood pressure fluctuates greatly even with pain, etc. Haemodialysis patients tend to fluctuate blood pressure before and after dialysis, because they cannot adjust their fluid volume.

4. Drug dose.

The use of NSAIDs may cause renal dysfunction. For renal excretory drugs, it is necessary to reduce the dose or extend the administration interval. For antibacterial agents, macrolides for hepatic metabolism, along with penicillin and cephem for renal excretion, are used.

Taking the above into consideration, the following four points should be noted when extracting third molars from CKD patients (Yamachika 2015; Ida et al. 2010):

1. Tooth extraction should be performed the day after dialysis in haemodialysis patients.
2. Prophylactic administration of antibacterial drugs is performed approximately 1 h prior to surgery.
3. Acetaminophen is used for the analgesic after tooth extraction. The dose of antibacterial drug should be reduced in accordance with the renal function.
4. Bleeding from the wound has to be completely stopped after tooth extraction (use a haemostatic agent and create a haemostatic plate).

Tooth Extraction While Undergoing Steroid Treatment

Corticosteroid therapy is indicated for autoimmune diseases such as rheumatoid arthritis and collagen disease, along with diseases such as nephrotic syndrome and thrombocytopenic purpura. Prolonged administration of corticosteroids causes disuse atrophy of the adrenocortex and pituitary gland, reducing the production of adrenocortical hormone from the adrenocortex and adrenocorticotropic hormone from the pituitary gland. Acute adrenocortical insufficiency develops when strong stress is applied in such patients. It is necessary to keep in mind that patients taking more than 5 mg of prednisolone daily for more than a month have a decreased adrenocortical function because 5 mg of prednisolone corresponds to the daily physiological secretion of corticosteroids. Therefore, corticosteroid replacement (steroid cover) is required prior to tooth extraction. If the invasiveness is at the level of tooth extraction, the patient should usually take twice the daily dose of corticosteroids in the morning of the treatment day. If an impacted tooth requires mucosal incision or osteotomy, 100 mg of Solucortef or Solumerdol is intravenously administered 1 hour prior to the procedure, with twice as usual dose is orally administered

Table 4.5 Comparison of synthetic steroids

Duration of action	Common name	Physiological daily secretion (mg)	Dose (mg)	Anti-inflammatory effect	Sodium retention	Half-line (hour)
Short time	Cortisol	20	20	1	1	8–12
	Cortisone-acetic acid	25	25	0.8	0.8	8–12
Intermediate	Prednisolone	5	5	4	0.3–0.8	12–36
	Methylprednisolone	4	4	5	0	12–36
	Methylprednisolone succinic acid	4	4	5	0	12–36
	Triamcinolone	4	4	5	0	12–36
Long time	Paramethasone	2	0.5	10	0	36–72
	Betamethasone	0.6	0.75–2.0	25	0	36–72
	Dexamethasone	0.75	0.5–0.75	25	0	36–72

following treatment (Asanoma et al. 2010). If more than 60 mg/day of cortisol or more than 15 mg/day of prednisolone is taken, additional administration prior to treatment is unnecessary because a sufficient amount of corticosteroids has already been administered (Table 4.5) (Otsuki 2008). Furthermore, long-term administration of corticosteroids can cause complications such as steroid diabetes, hypertension, peptic ulcer, and osteoporosis. If the patient has a peptic ulcer, attention must be paid to the administration of anti-inflammatory analgesics. We should also consider extending the antibiotic administration period after tooth extraction, because it can be susceptible to infections and delay wound healing (Goto and Goto 2015).

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5 Drug Holiday in Mandibular Third Molar Extraction

Toshiro Kibe

Introduction

In general, patients receiving certain drugs, such as antiplatelet and anticoagulant drugs, require drug holidays before surgery. In oral surgery, several drugs may require drug holidays. Among oral surgeries, mandibular third molar extraction is performed most frequently. To date, several postoperative complications need to be considered. Various complications of mandibular third molar extraction have been reported, including post-extraction infection, post-extraction bleeding, swelling, difficulty in opening, nerve injury, dry socket (alveolar osteitis), and osteonecrosis of the jaw. Among them, post-extraction bleeding, dry socket, and osteonecrosis of the jaw have been reported as drug-induced post-extraction

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complications; therefore, drug holidays may be recommended in such cases. Recently, with the aging of dental patients, there are more opportunities to perform extractions in patients with multiple medical histories or those who take many medications. Therefore, it is necessary to thoroughly check the medications before extraction. This section discusses the concept of drug holidays in relation to post-extraction complications strongly associated with the drugs patients take during mandibular third molar extraction: post-extraction haemorrhage, osteonecrosis of the jaw, and dry socket.

A Drug Holiday Approach to Antithrombotic Therapy

There are two types of oral antithrombotic drugs (Table 5.1):

- Anticoagulants such as warfarin and direct-acting oral anticoagulants (DOACs)
- Antiplatelet drugs such as aspirin and adenosine diphosphate (ADP) receptor inhibitors

Anticoagulants are used in the treatment of certain conditions of the blood vessels, heart, and lungs, including atrial fibrillation, peripheral arterial disease, and venous thrombosis. ADP receptor inhibitors are a class of antiplatelet agents used in the treatment of acute coronary syndrome or in preventive treatment for patients who are at risk of thrombosis, myocardial infarction, or stroke. As a general rule, any oral antithrombotic medication should not be withdrawn when the risk of bleeding is low, such as simple extraction of an erupted mandibular third molar. The rationale for not withdrawing the drug is based on reports that about 1% of patients who discontinue warfarin for tooth extraction develop a serious stroke and may die and that discontinuing aspirin increases the incidence of stroke by 3.4 times (Fakhri et al. 2013). However, oral antithrombotic drugs may be discontinued when the risk of post-extraction bleeding is high, such as in the extraction of impacted teeth that require mucosal incision or osteotomy, or when anticoagulants and antiplatelet agents are used in combination (Table 5.2).

Table 5.1 Antithrombotic drugs (inhibition of thrombosis)

	Anticoagulants	Antiplatelet
Category	Warfarin	Aspirin preparations
	Direct-acting oral anticoagulants (direct thrombin inhibitor, factor Xa inhibitor)	ADP receptor inhibitors
		PDE inhibitors
Indications	Venous thrombosis	Arterial thrombosis
	Atrial fibrillation	Cerebral infarction
	Others	Others

Table 5.2 Specific examples of drug holidays of medication due to bleeding risk

Drugs		Bleeding risk	
		Low (simple tooth extraction)	High (invasive tooth extraction)
Antiplatelets	Aspirin preparations	No drug holidays	7 days
	ADP receptor inhibitors	No drug holidays	7 days
	PDE inhibitors	No drug holidays	3 days
Anticoagulants	Warfarin	INR 3.0[a] or less can be used for tooth extraction	5 days
	Direct thrombin inhibitor[b]	No drug holidays	17 h
	Factor Xa inhibitor[b]	No drug holidays	12 h

[a]There are large individual differences in the anticoagulant effect produced by warfarin administration
[b]Direct-acting oral anticoagulants

Anticoagulant Drugs

There have been numerous studies with a high level of evidence that report no serious bleeding complications in patients taking warfarin who have stable primary disease and a therapeutically controlled prothrombin time-international normalized ratio (PT-INR) test, even if the patients undergo tooth extraction while remaining on warfarin (Devani et al. 1998; Evans et al. 2002; Dunn and Turpie 2003; Nematullah et al. 2009). Considering the risk of discontinuing warfarin, extraction should be performed with continuous warfarin in general. The PT-INR is an indicator for dosage adjustment of the anticoagulant warfarin, and it is recommended that PT-INR be used as an indicator for dental treatment (Steinberg and Moores 3rd 1995). According to previous reports, it is possible to perform dental extractions under continuous warfarin if the PT-INR is below 3.0 in Asians and below 4.0 in Americans and Europeans (Perry et al. 2007; Aframian et al. 2007). The average dose of warfarin is lower in Asians such as the Japanese and Chinese compared to Caucasians and African-Americans, and the existence of ethnic differences has also been reported. It is reasonable to assume that the PT-INR is less than 3.0 in Asians and less than 4.0 in other ethnic groups when performing dental extractions under continuous warfarin. However, few studies have provided clear criteria for PT-INR for extractions that require gingivectomy or bone removal, such as impacted tooth extraction. There are some reports that a PT-INR of up to 3.5 can be used for extraction of impacted teeth and multiple teeth with reliable haemostasis and that a PT-INR of ≤2.5 can be safely used for extraction of impacted teeth (Herman et al. 1997; Lockhart et al. 2003). From the author's experience, I agree with these reports. In fact, patients with a PT-INR of

2.5 or higher may have difficulty with haemostasis after extraction of an impacted mandibular third molar. It is possible to extract a mandibular third molar without excessive postoperative bleeding, while continuing warfarin, if there are no other risk factors (liver disease or impaired vitamin K intake) and the PT-INR is less than 2.5. However, local haemostasis needs to be performed appropriately; therefore, if the operator is not familiar with haemostatic procedures, it may be safer to refer the patient to an oral surgery specialist.

Several techniques can be employed to reduce post-extraction complications due to bleeding risk in the extraction of impacted teeth. First, acute inflammation should be reduced prior to the procedure; secondly, lingual mucoperiosteum should not be elevated; thirdly, bone removal should be minimized; fourthly, inflammatory granulation should be removed; and finally, the wound should be sutured to stabilize the extraction socket. Recently, an increasing number of patients are taking DOACs instead of warfarin for anticoagulation. It should not be a serious issue even if bleeding due to tooth extraction is difficult to control, because DOACs lose their effect about 1 day following a withdrawal (Table 5.2).

Antiplatelet Drugs

Antiplatelet agents inhibit platelet aggregation, which increases the risk of bleeding during tooth extraction (Van Cann and Koole 2008). In contrast, interruption of antiplatelet therapy is associated with a risk of thromboembolism, such as cerebral infarction (Armstrong et al. 2006). Therefore, in principle, it is better to continue antiplatelet therapy as well as anticoagulants for tooth extraction. In a study investigating tooth extraction while continuing to take antiplatelet medication, it was reported that post-extraction bleeding did not occur in either group, although the bleeding time was prolonged within the normal range in the continued aspirin group (Ardekian et al. 2000). In another study, it was reported that there was no severe bleeding when extractions were performed with aspirin, and only minor bleeding occurred in 2% of patients, which could be stopped by applying local haemostatic measures (Madan et al. 2005). Therefore, the risk of developing serious bleeding complications, even if tooth extraction is performed with continuous antiplatelet medication, is lower than when taking anticoagulants. In addition, interruption of antiplatelet medication at the time of tooth extraction increases the risk of cerebral infarction; therefore, the author recommends performing tooth extraction under continuous antiplatelet medication. If an extraction is performed on a patient who is on both antiplatelet and anticoagulant medications and is at high risk for bleeding, one may wish to consider withdrawing one of the medications. In such cases, the author recommends withdrawal of the antiplatelet agent with a relatively low risk of interruption.

A Drug Holiday Approach to Medication-Related Osteonecrosis of the Jaw

Bisphosphonates (BPs) are drugs that inhibit bone resorption by suppressing the action of osteoclastic cells and are widely used in the treatment of cancer patients with bone metastases and osteoporosis. In 2003, it was reported that rare but refractory osteonecrosis of the jaw (BP-related osteonecrosis of the jaw, BRONJ) could occur in patients with cancer or osteoporosis treated with BP (Marx 2003). Initially, the mechanism of the disease was unclear, causing confusion in clinical practice. However, with the accumulation and review of cases, a better understanding of its pathogenesis has been established, and a consensus on the treatment of BRONJ is being established. It is also known that denosumab also causes ONJ, similar to BP, although the mechanism of action is different (DRONJ, denosumab-related ONJ). In addition, similar ONJs may occur in patients receiving angiogenesis inhibitors or molecular targeted therapies, which are often used in combination with anticancer drugs for cancer treatment (Fig. 5.1). Regarding the name of the disease, the American Association of Oral and Maxillofacial Surgeons (AAOMS) proposed the name medication-related osteonecrosis of the jaw, MRONJ, (medication-related ONJ), which will be used in this section.

Drug Holiday Before Invasive Dental Procedures Such as Third Molar Extraction

There has been significant debate about whether to continue bone resorption inhibitor treatment as is or to take a break when performing dental procedures on patients treated with bisphosphonates. The key points to this debate are as follows:

1. It is unclear whether withdrawal of bisphosphonates prevents the occurrence of MRONJ.
2. Withdrawal of bisphosphonates increases the incidence of bone density loss and fractures in osteoporotic patients (Taguchi et al. 2015, 2016; Curtis et al. 2008).
3. The benefit of fracture prevention outweighs the risk of developing MORNJ (Black and Rosen 2016).

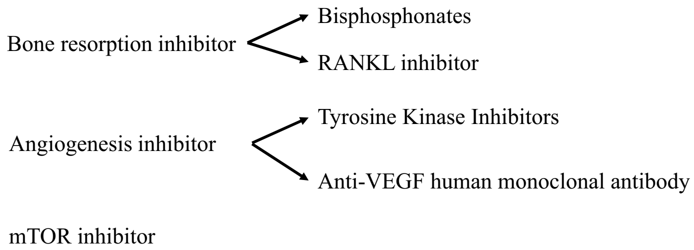


Fig. 5.1 Types of drugs related to osteonecrosis of the jaw

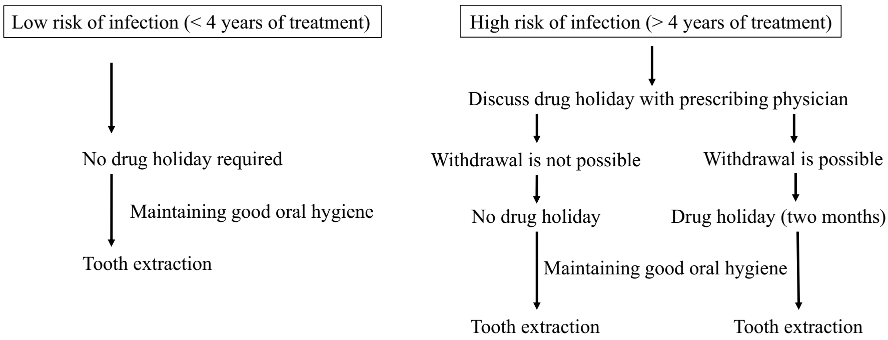


Fig. 5.2 Protocol for patients taking bisphosphonates prior to tooth extraction

4. The occurrence of MORNJ is attributed to bacterial infection, and it has been reported that the occurrence of MRONJ can be reduced if infection prophylaxis is used before dental treatment (Otto et al. 2015).

Based on these evidence-based perspectives, bisphosphonates should not be withdrawn before invasive dental procedures, such as mandibular third molar extraction.

However, the AAOMS reported an increased incidence of MRONJ in osteoporotic patients when BP treatment lasted longer than 4 years. Therefore, the AAOMS advocates that when invasive dental procedures are performed on patients receiving bisphosphonates for more than 4 years or osteoporosis treatments with a high risk of infection, a 2-month withdrawal of bisphosphonates should be discussed with the attending physician if the patient's general condition, including fracture risk, permits (Ruggiero et al. 2014) (Fig. 5.2).

In addition to bisphosphonates, bone resorption inhibitors include denosumab, a RANKL inhibitor. The incidence of MRONJ with denosumab has been reported to be similar to that of bisphosphonates (Saad et al. 2012). As with bisphosphonates, invasive dental procedures such as tooth extractions should be performed with thorough oral hygiene, and, in principle, no withdrawal denosumab has a half-life of 1 month and the timing of tooth extraction can be considered in light of the fact that denosumab should be administered once every 6 months to osteoporotic patients.

When to Restart Bone Resorption Inhibitors

If the drug is withdrawn for an invasive dental procedure, such as tooth extraction, treatment with bone resorption inhibitor should be resumed approximately 2 months after the surgery, when the invasive dental site has sufficiently healed. However, if it is necessary to accelerate the resumption of administration due to the condition of the primary disease, it is possible to wait only 2 weeks after tooth extraction when epithelialization of the wound is almost complete and resume administration after confirming that the wound is free of infection.

A Drug Holiday Approach to Dry Socket Caused by Oral Contraceptives

Many women in their 20s and 30s are patients who undergo extraction of mandibular third molars. Some of the patients are taking oral contraceptives which can develop the dry socket. A systematic review reported that oral contraceptives are a risk factor for the development of dry sockets (Tarakji et al. 2015). Another report found that patients who were taking oral contraceptives at the time of tooth extraction were about four times more likely to develop dry socket than those who were not taking oral contraceptives (Almeida et al. 2016). Many oral contraceptives inhibit the formation of blood clots in extraction sockets by altering blood levels of coagulation and fibrinolytic factors. If a patient is taking oral contraceptives, it is recommended to avoid extractions during the first 3 weeks of contraceptive use and to extract the teeth during the withdrawal period of the third or fourth week.

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Part II

Evidence of Surgical Complications

Inferior Alveolar Nerve Block and Its Complications

6

Yasuhiko Kamura and Joe Iwanaga

Introduction

The inferior alveolar nerve block (IANB) is one of the most commonly used anaesthetic techniques that clinicians utilize in their daily practice. Complications associated with IANB vary from being common to rare and include pain and trismus produced by insertion or by the withdrawal of the needle (Smyth and Marley 2010; Wright 2011), needle breakage (Ethunandan et al. 2007), and facial paralysis caused by inadvertent deposition of local anaesthesia (Chevalier et al. 2010; Tzermpos et al. 2012). Hematoma may also develop due to the damage of blood vessels, as well as following the intravascular disturbance. Ptosis and extraocular muscle paralysis (Yoon and Chussid 2012), aphonia (He and Chen 2012), necrosis

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of the skin of the chin (Torrente-Castells et al. 2008), diplopia, and abducent nerve palsy were also reported as complications following IANB (Surej Kumar et al. 2010; Choi et al. 2009).

Pain and Trismus

The mucosa tearing may cause pain and trismus during the progression or withdrawal of the needle (Smyth and Marley 2010). Pain at the site of injection is one of the most common complications of local anaesthesia in the oral cavity. This condition is almost always self-limiting and will resolve within 5–10 days without any definitive treatment. Nonsteroidal anti-inflammatory drugs (NSAIDs) should be taken every 4 h by the clock rather than "as needed" until the pain is manageable.

Trismus is also a relatively common complication following IANB. The cause of trismus is usually injection into muscles that damages the muscle fibres and leads to limitations in the opening. The muscle commonly causing trismus is the medial pterygoid muscle, which can be penetrated or damaged during IANB (Wright 2011). The pain that is engendered with needle insertion causes the muscles to contract, resulting in limited muscle movement. Hematoma formation may also cause muscle spasms and trismus. Hematomas may develop due to the injury to the pterygoid venous plexus or following the injury of the inferior alveolar vessels (Fig. 6.1). NSAIDs should be considered for the first 48 h, and the condition should be monitored closely. If no improvement in mouth opening is noted, then treatment of the trismus should begin. The improvement should be noted within 3–5 days following

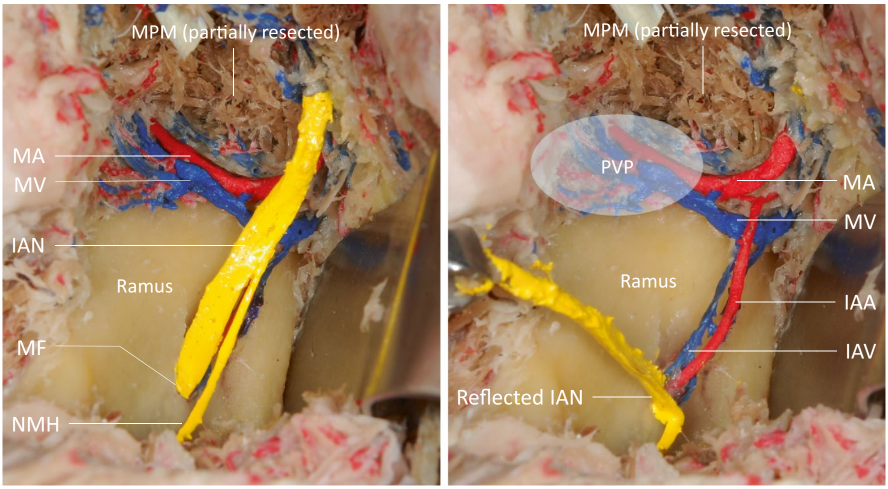


Fig. 6.1 Anatomy of the pterygomandibular space. Note the pterygoid venous plexus (PVP), maxillary artery (MA), maxillary vein (MV), inferior alveolar artery (IAA), and inferior alveolar vein (IAV) are all in close proximity. *MF* mandibular foramen, *MPM* medial pterygoid muscle, *NMH* nerve to mylohyoid muscle

the initiation of management. Trismus occurring 2 or 3 days after the iANB is most likely a needle tract infection and needs be treated with oral antibiotics (Ogle 2012).

Nerve Damage

One of the most discussed complications is the nerve damage after IANB. Injury to the nerves can be one of the most serious complications that can arise from the performance of a number of dental procedures. While the incidence of permanent nerve damage is rare, dentists should be aware of how it happens and how to prevent it. The incidence of nerve damage was reported at between 1 in 26,762 and 1 in 160,571 (Pogrel and Thamby 2000). Krafft and Hickel (1994) reported sensory alteration in the lingual nerve in 18 out of 12,104 patients. In 17 out of the 18 patients, sensation recovered after 6 months of injection. These nerve damages are considered to be caused by trauma caused by needle, haemorrhage within the epineurium, or a neurotoxic side effect from the local anaesthetics. Direct trauma was possibly caused by the damaged tips when the surface of the mandible was contacted during the injection (Rout et al. 2003, Stacy and Hajjar 1994). An incidence of 60% to 97% barbed needle tip damage was found when needles were examined following an IANB (Fig. 6.2). Stacy and Hajjar (1994) also concluded that the withdrawal of damaged needles could cause nerve damage to the inferior alveolar or lingual nerve. However, the author believes the inferior alveolar nerve is much less likely to get damaged by withdrawal of damaged needles based on the anatomical relationship between the injection site and inferior alveolar nerve. According to Montserrat-Bosch et al. (2014), the modified IANB in a more inferior position extends the onset time, does not seem to reduce the risk of intravascular injections, and might increase the risk of lingual nerve injuries.

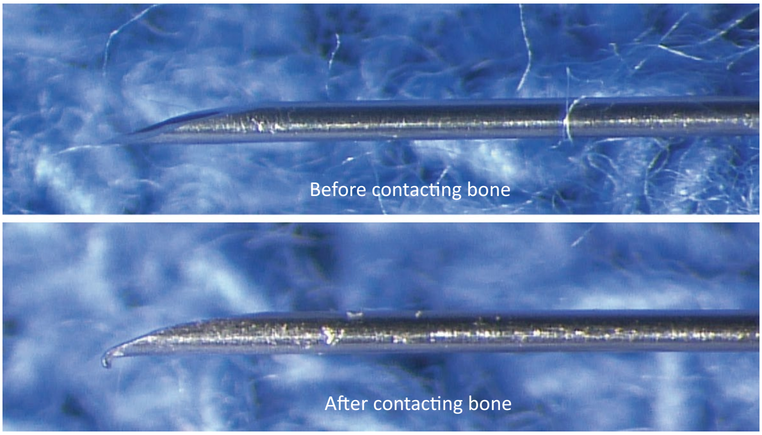


Fig. 6.2 Needle tip damage after contacting the surface of the mandible

Some reported the incidence of local anaesthetic-induced neuropathies (ones that involved the lip and/or tongue) was approximately five times higher with articaine and prilocaine than either lidocaine or mepivacaine (Haas and Lennon 1995; Miller and Lennon 2000). According to Gaffen and Haas (2009) and Garisto et al. (2010), articaine and prilocaine had a higher incidence of paraesthesias: one in 2,070,678, 4,159,848, and 181,076,673 injections for prilocaine, articaine, and lidocaine, respectively. According to the literature above, you can see many reports suggesting that articaine has a higher risk of neuropathies based on retrospective data. Pogrel (2012) evaluated patients with permanent nerve damage from IANB and found that the lidocaine was associated with 35%, with articaine causing approximately 30% of the cases. The authors concluded that IANB can cause permanent nerve damages, regardless of the local anaesthetic used, and that they did not find any disproportionate nerve involvement from articaine. Other studies also showed that there is neither a significant clinical advantage nor a significant risk of developing paraesthesia when using articaine for an IANB instead of other dental anaesthetics (Wells and Beckett 2008, Yapp et al. 2011). Even though there is a statistically higher incidence of paraesthesias with articaine and prilocaine, the numbers themselves are not clinically significant. It has to be noted that clinicians have to very carefully monitor and evaluate the condition with any paraesthesia. Documentation of the patient's reported area of altered sensation, the type of altered sensation (e.g., anaesthesia, paraesthesia, or dysesthesia), and regular follow-up are necessary.

Facial paralysis has been also reported following IANB that could be caused if the injection is administered too far posteriorly in the parotid gland region. Paralysis of the lingual nerve, paraesthesia, or dysesthesia has also been most often reported.

There might be no conclusive way to prevent the risk of nerve damage resulting from IANB. However, it is possible that the needle could be traumatizing the lingual nerve if the patient feels an "electric shock" in the tongue. A clinician has better change the injection site, which may minimize the incidence of permanent nerve damage. Most patients with nerve damage are managed with reassurance and medication such as high-dose corticosteroids to reduce the immune-inflammatory reaction. Most paraesthesia resolves within 10 to 14 days; however, this may take up to 6 months. On rare occasions, it may be permanent (Ogle 2012).

Positive Aspirations

Injection to pterygomandibular space during IANB has a high risk of accidental intravascular injection of local anaesthetic that may result in cardiovascular and central nervous system toxicity, as well as tachycardia and hypertension (Lustig and Zusman 1999; Bennett 1984; Frangiskos et al. 2003). Aspiration before administration of local anaesthetics could prevent the incidence of adverse reactions. Various authors have found that positive aspirations occur from 4% to 16% during IANB (Fig. 6.3). A local anaesthetic with 1:100,000 vasoconstrictor does not cause substantial changes to the cardiovascular system when intravascular injection of the local anaesthetic is avoided (Brownbill et al. 1987, Vasconcellos et al. 2008;

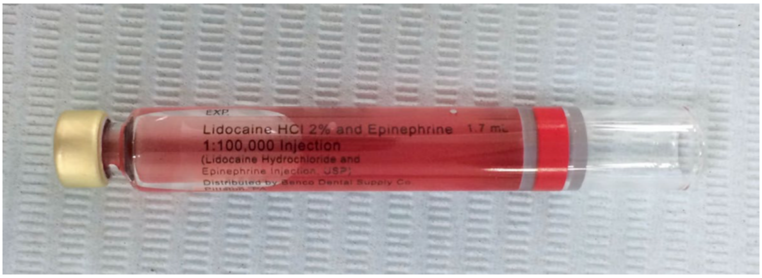


Fig. 6.3 Positive aspiration occurred during inferior alveolar nerve block

Danielsson et al. 1984, Kuster and Udin 1985, Delgado-Molina et al. 1999, Delgado-Molina et al. 2003). However, greater concentrations such as 1:50000, or the rapid intravascular injection of local anaesthetic solution, may have harmful hemodynamic effects for patients with cardiovascular disease (Bader et al. 2002).

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Mandibular Third Molar Extraction and Inferior Alveolar Nerve Injury

7

Kiyosato Hino, Yushi Abe, Shogo Kikuta, and Joe Iwanaga

Introduction

The inferior alveolar nerve (IAN) runs in the mandibular canal. However, due to its anatomical location, this nerve is at risk of injury during various dental procedures such as dental implant placement, orthognathic surgery, and extraction of the mandibular third molar. In this chapter, we will review the inferior alveolar nerve injury caused by the mandibular third molar extraction.

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Definition of Inferior Alveolar Nerve Injury

The mandibular third molar extraction is reported as one of the most common cause of injury of the IAN (Tay and Zuniga 2007). When the IAN gets injured, sensory loss can occur. In a few rare cases, pain may occur (Townend 1995). Neuropathy caused by injury of the IAN has been classified into three categories by Seddon (1943) (Fig. 7.1). Among them, the transient conduction defects (neurapraxia) due to only partial exposure or contact to the nerve fibres are likely to regenerate over time, and most injuries heal after 3–4 months (Kjølle and Bjørnland 2013). If the injury is more than an axonal tear (axonotmesis) or a nerve fibre tear (neurotmesis), it is unlikely to heal spontaneously and requires therapeutic intervention due to the high degree of nerve invasion, e.g. nerve repair (Table. 7.1). In general, postoperative neurosensory deficits, such as numbness and dysesthesia, are considered temporary if they subside within 6 months, while the deficits are considered permanent if abnormal symptoms persist for 6 months (Gülicher and Gerlach 2001; Jain et al. 2016; Korkmaz et al. 2017; Wang et al. 2018; Kubota et al. 2020). Recovery after 9 months postoperatively is extremely rare, and recovery after 18–24 months of follow-up is almost impossible (Robinson 1988).

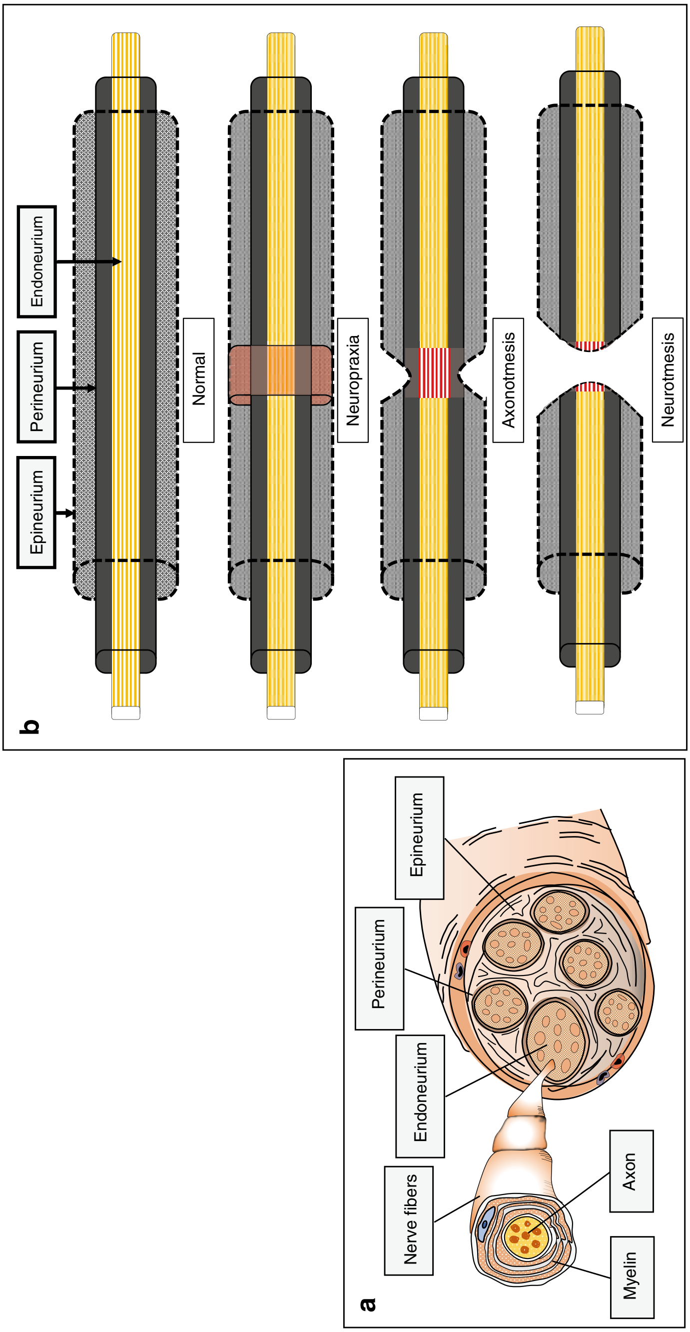


Fig. 7.1 Seddon's classification (1943). (**a**) Schematic diagram of a sensory nerve. (**b**) Seddon's nerve injury classification. The image shows the three types of nerve damage in order of severity, with normal nerve damage at the top. Neuropraxia is a temporary blockage of nerve transmission, and axonotmesis is an abnormality of axons in the endoneurium and neurotmesis shows nerve rupture

Table 7.1 Classification of inferior alveolar nerve injury by Seddon (1943)

	Neurapraxia	Axonotmesis	Neurotmesis
State	Temporary interruption of conduction	Axon severed, endoneurial tube intact Severing endoneurium, epineurium intact	Division of the nerve
Symptom	Paraesthesia	Paraesthesia，hypoesthesia，dysesthesia	Anaesthesia, intractable pain
Cause	Nerve exposure Direct blunt injuries Temporary traction Temporary compression	Direct blunt injuries Mechanical traction/pressure Compression sudden or prolonged	Complete amputation with scalpel or bur Electrocautery burns/cuttings
Prognosis	1 to 2 weeks up to 1 month	Slow healing (12 months) 2–6 months after the cause eliminated	Might recover with appropriate treatment within 80% within 1 year, 90% within 2 years
Treatment	Natural healing	Natural healing or surgical intervention	Surgical intervention

Anaesthesia:Total loss of feeling or sensation
Dysesthesia:Abnormal sensation which is unpleasant
Paraesthesia:Abnormal sensation that is not unpleasant
Hypoesthesia:Decreased sensitivity to stimulation

Incidence of IAN Injury

The incidence of IAN injury caused by mandibular third molar extraction varies in reports (Table 7.2). Bruce et al. (1980) reported that IAN paraesthesia occurred in 44 (4.4%) of 990 mandibular third molar extractions (Bruce et al. 1980). Subsequent reports varied and ranged from 0.35% to 19% when the root of the mandibular third molar was very close to the IAN (Carmichael and McGowan 1992; Haug et al. 2005; Cheung et al. 2010; Hasegawa et al. 2013; Kjølle and Bjørnland 2013; Smith 2013; Guerrero et al. 2014; Martin et al. 2015). There is also a report that postoperative paraesthesia occurred in 2.4% of 291 extractions performed by a single dentist that required bone grinding or splitting (Contar et al. 2010). The incidence of IAN injury up to 7 days after extraction of mandibular third molar was 1–5%, while the incidence of perceptual abnormality after 6 months was reported to be 0–0.9% (Hillerup 2007). Therefore, it is necessary to consider whether post-extraction perceptual abnormalities are transient or permanent. A review of 44,171 mandibular third molar teeth (in 26,427 patients) from 23 studies by Kang et al. (2019) reported that transient IAN injury occurred in 532 (1.20%) and permanent IAN damage in 126 (0.28%) (Kang et al. 2019). And in most cases, the perceptual abnormality is temporary and recovers within 6 months, but in less than 1% of cases, the abnormality lasts longer and often becomes permanent (Smith et al. 1997; Gülicher and Gerlach 2001; Jerjes et al. 2010; Momin et al. 2013; Eshghpour et al. 2017). The incidence of IAN injury caused by the extraction of mandibular third molar can be

Table 7.2 Incidence of inferior alveolar nerve injury

Study	Year	Study type	Cases/total (n)	Age	Sex	Number of patients with permanent damage to IAN	Factors that showed significant differences
Bruce	1980	PS	44/900 (4.89%)	–(≦24:4,24<:40)	–	–	Age
Kipps	1980	RS	60/1377 (4.4%)	Mean:28.5, control:24.3	M:19, F:35	14(1.0%)	Use of burs and surgical removal of bone, radiographic findings, intraoperative nerve exposure/haemorrhage
Chiapasco	1995	—	7/1500 (0.47%)	–(≦24:1,24<:6)	–	1(0.07)	–
Haug	2005	PS	61/4403 (1.39%)	–(≦25)	–	–	–
Nakamori	2008	RS	7/695 (1.01%)	Mean:–, control:31.4	–	0	The panoramic images
Cheung	2010	PS	15/4338 (0.35%)	Mean:28.7, control:27.2	M:6, F:9	5(0.12%)	Depth of impaction
Contar	2010	RS	6/863 (2.40%)	Mean:25.6, control:–	M:2, F:3	0	–
Hasegawa	2011	—	34/2528 (1.3%)	Mean:38.5, control:31.8	M:17, F:15	–(0.6%)	Age, surgeon experience, procedure-related factors during surgery, radiographic signs
Guerrero	2013	RCT	7/256 (2.73%)	–	–	–	–
Hasegawa	2013	RS	28/440 (6.4%)	Mean:40.5, control:35.4	M:14, F:12	8(1.8%)	Panoramic radiographic signs, excessive haemorrhage during extraction, a close relationship of the roots to the IAN on CT examination
Kjølle and Bjørnland	2013	PS	11/1220 (0.8%)	Mean:38.6, control:27	M:4, F:7	5(0.4%)	Age, cortical line interruption
Smith	2013	PS	40/1589 (2.5%)	–	–	6(0.37%)	Bone removal and tooth division
Korkmaz	2017	PS	14/139 (11.5%)	–(≦25:2,25<:12)	M:8, F:6	0	–
Ramadorai	2019	RS	8/1276 (0.62%)	Mean:30.0, control:30.5 (≦25:2,25<:12)	M:3, F:5	1(0.08%)	Race, OPG canal and root, radiological signal
Kubota	2020	RS	27/1177 (2.29%)	Mean:39, control:31 (≦30:4,30<:21)	M:7, F:18	–	Lingual/inter-radicular IAC position to LM3, multiple roots with perforated IAC, age

PS prospective study, *RCT* randomized controlled trial, *RS* retrospective study

affected by various factors. This is probably the reason for the variability in the reported incidence. Each of the following risk factors should be considered when considering the risk in each patient.

IAN Injury and Sex

According to a systematic review by Kang et al. (2019), the incidence of IAN injury in males and females was 1.48% and 1.10%, respectively, with no statistical difference (Kang et al. 2019). Other studies have also found no association between sex and IAN injury (Kipp et al. 1980; Valmaseda-Castellón et al. 2001). However, some studies have shown that female patients have a higher probability of IAN injury than males (Valmaseda-Castellón et al. 2001; Hillerup 2007; Kim et al. 2012). Anatomy and temperament have been cited as reasons for the variance in results between reports. Hillerup (2007) pointed out that females may be at higher risk because they are more likely to see a doctor, but it should not affect the "percentage" (Hillerup 2007). Nakagawa et al. (2007) reported that females have a thinner mandibular cortex and a smaller distance between the teeth and the mandibular canal, which could increase the risk of nerve damage (Nakagawa et al. 2007). They concluded that sex itself would not be a risk factor for IAN injury but difference in anatomical distance.

IAN Injury and Age

IAN injuries are generally more common in patients older than 30 years. Many studies have supported that patients with IAN injury are significantly older than those without injury (Bruce et al. 1980; Chiapasco et al. 1995; Valmaseda-Castellón et al. 2001; Kim et al. 2012; Korkmaz et al. 2017; Kubota et al. 2020). Another study has shown that the mandibular third molars in females aged 50–70 years are significantly closer to the IAN (meaning mandibular canal) than those of patients under 30 years old (de Bruyn et al. 2020).

Although some studies do not support the idea that age is a risk factor for IAN injury (Kipp et al. 1980; Townend 1995; Valmaseda-Castellón et al. 2001; Cheung et al. 2010), the following anatomical features have been identified as factors that make elderly patients more prone to IAN injuries: decreased bone elasticity, narrowed periodontal space, increased incidence of tooth calcification, enhanced tooth hypercementosis, sclerotic changes in the surrounding bone, and delayed regeneration of the injured nerve, the proximity of the mandibular third molar root apex to the mandibular canal (Nakamori 2014; Nguyen et al. 2014; Valmaseda-Castellón et al. 2001; Miyamoto et al. 2013) .

The number of days those adverse events persist after the extraction correlates with age. It was significantly longer in patients over 35 years of age, about three times longer than in patients under 25 years of age (Bruce et al. 1980). The speed of nerve recovery after injury is also correlated with age; the younger the patient, the

faster the overall recovery (Zuniga 1992; Donoff 1995). Studies in animal models have shown that during regeneration of damaged nerves, older animals have slower axonal regeneration speed and shorter maintenance of regenerative response (Vaughan 1992). The factor of "old age" during mandibular third molar removal is a factor that should be noted before and after extraction.

IAN Injury and the Root Formation

According to Chiapasco et al. (1995), the nerve injury in the group with closed apex after root formation (>24 years old) was 1.4% (6/430), those of 9–16 years was 0% (0/500), and those of 17–24 years was 0.2% (1/570). This group was categorized based on the age of the root formation (see Chap. 1). The incidence of the IAN injury after root formation could be higher than before root formation when the IAN is anatomically at a risk.

IAN Injury and Radiologic Signs

Although the incidence of IAN injury varies with position and degree of the mandibular third molar, (Sarikov and Juodzbalys 2014) reported that horizontal impaction in close radiographic proximity to the mandibular canal is at a risk of injury (Sarikov and Juodzbalys 2014). Ramadorai et al. (2019) also reported that the incidence of IAN injury was highest (4.7%) when the tooth was horizontally impacted and lowest (0.9%) with vertical impaction. In other words, when considering IAN injury, it is very important to have radiographic images that can confirm the impaction of the mandibular third molar and its positional relationship with the mandibular canal.

As for the relationship between the mandibular third molar and the mandibular canal, Rood and Nooraldeen Shehab (Rood and Nooraldeen Shehab 1990) proposed the following seven image signs in panoramic radiographs. The following seven signs in panoramic radiographs were proposed as the relationship between the mandibular third molar and the mandibular canal: (1) darkening of the apical root, (2) deflection of the roots, (3) narrowing of the roots, (4) dark and bifid apex of the root, (5) interruption of the white line(s), (6) diversion of the mandibular canal, and (7) narrowing of the mandibular canal. It is concluded that three of them, namely, diversion of the mandibular canal (44.4%), darkening of the apical root (18.9%), and interruption of the white line (11.5%), are significantly associated with IAN injury (Rood and Nooraldeen Shehab 1990; Atieh 2010; Wenzel 2010; Kang et al. 2019) (Figs. 7.2 and 7.3). In addition, position C of the Pell-Gregory classification known as the positional classification of mandibular third molar was not significantly associated with sensory disturbance (Wang et al. 2018; Kubota et al. 2020). Either position or class of the Pell-Gregory classification should not be used to evaluate the risk of IAN injury as those were not based on the relationship between the mandibular third molar and mandibular canal.

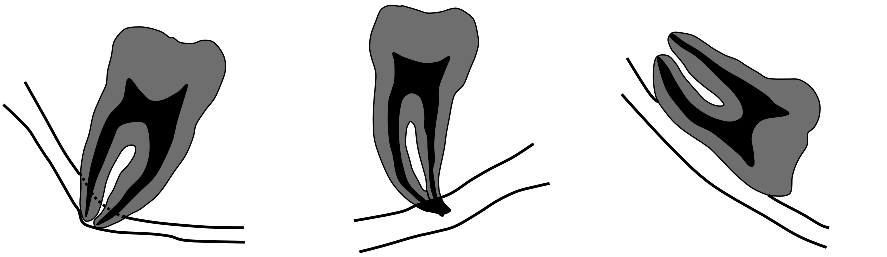


Fig. 7.2 Images of three high-risk signs on panoramic radiographs by Rood and Shehab. Note that three of the seven imaging signs are significantly associated with IAN injury

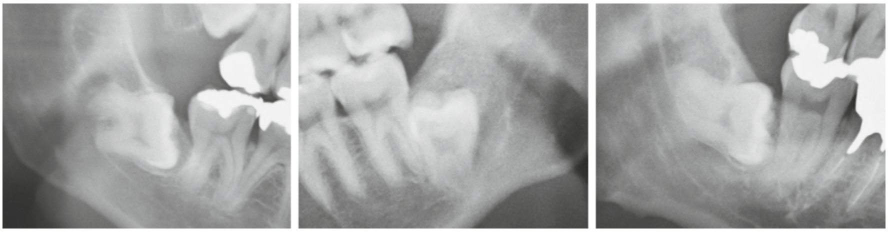


Fig. 7.3 Panoramic radiography findings associated with IAN injury

Cone-beam computed tomography (CBCT) can provide a three-dimensional representation of the anatomical position of the mandibular third molar and the mandibular canal (Sklavos et al. 2021). Among the CBCT findings, teardrop-like MC, and dumbbell-shaped MC, lingual/inter-radicular MC positions are thought to be associated with IAN injury (Wang et al. 2018; Kubota et al. 2020) (Fig. 7.4). In addition, the lingual/perpendicular position of the IAN to the mandibular third molar and the presence of roots perforating the MC are also risk factors (Kubota et al. 2020). Especially, perforation of the MC wall by mandibular third molar is a major risk factor for IAN injury (Ueda et al. 2012). Interestingly, it is reported that CBCT imaging does not significantly reduce the frequency of IAN injury (Clé-Ovejero et al. 2017; Korkmaz et al. 2017; Baqain et al. 2020). However, prior understanding of the three-dimensional structures listed as risk factors (see above) can indicate the modification of certain surgical techniques such as crown resection, bone removal, and the use of dental elevator (Hasegawa et al. 2013; Qi et al. 2019).

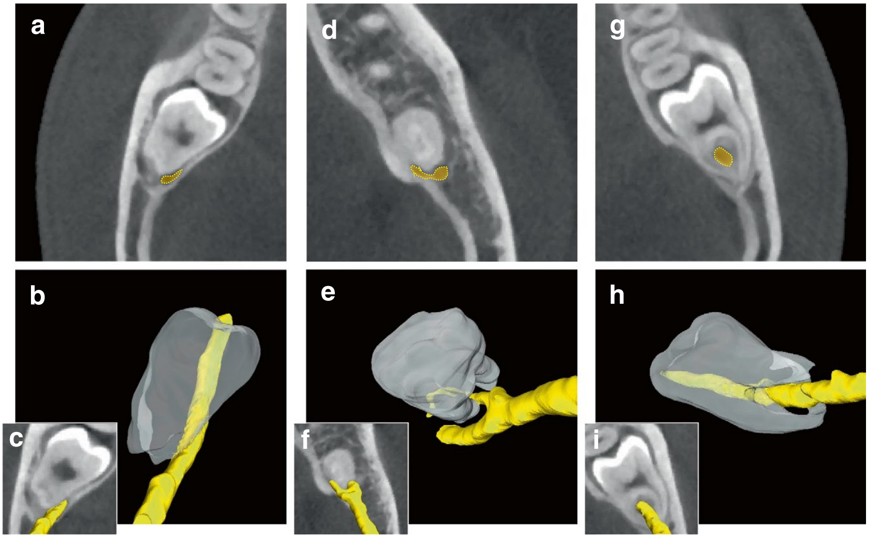


Fig. 7.4 Axial CBCT findings associated with IAN injury (**a**, **d**, **g**). The lower images are 3D reconstructions of the mandibular third molar and IAN from the respective CBCT images; the 3D reconstruction shows that the mandibular third molar and IAN are closely related (**b**, **e**, **h**). Merging CT images with 3D reconstructed IAN (**c**, **f**, **i**)

IAN Injury and Intraoperative Nerve Exposure/Haemorrhage

Concerning nerve exposure, they reported that permanent IAN injury occurred in 24 (38.7%) of the 62 IAN exposures observed intraoperatively (Wang et al. 2018). In a study that reviewed 3270 cases, the incidence of IAN deficit was 12.5 times higher when the nerve was exposed intraoperatively (23.0%) than when no exposure was confirmed (1.6%) with a statistically significant difference (Kang et al. 2019). Especially when the mandibular canal runs lingual to the mandibular third molar, the IAN exposure is higher (Jhamb et al. 2009). This is probably as the rate at which the mandibular canal contacts the root surface is higher on the lingual side and between the roots than on the buccal side (Maegawa et al. 2003). It has been reported that 9 out of 11 patients (81.81%) who had intraoperative haemorrhage or IAN exposure had nerve damage (Jain et al. 2016). This suggests that regardless of nerve exposure, intraoperative bleeding increases the possibility of IAN injury (Fig. 7.5). Even if the IAN bundle is intact, nerve compression or contusion is suspected if sensory disturbances occur, and nerve regeneration usually takes several weeks to 6 months (Zuniga 1992). If intraoperative nerve exposure or bleeding occurs, a patient explanation should be given, and the postoperative course should be carefully monitored.

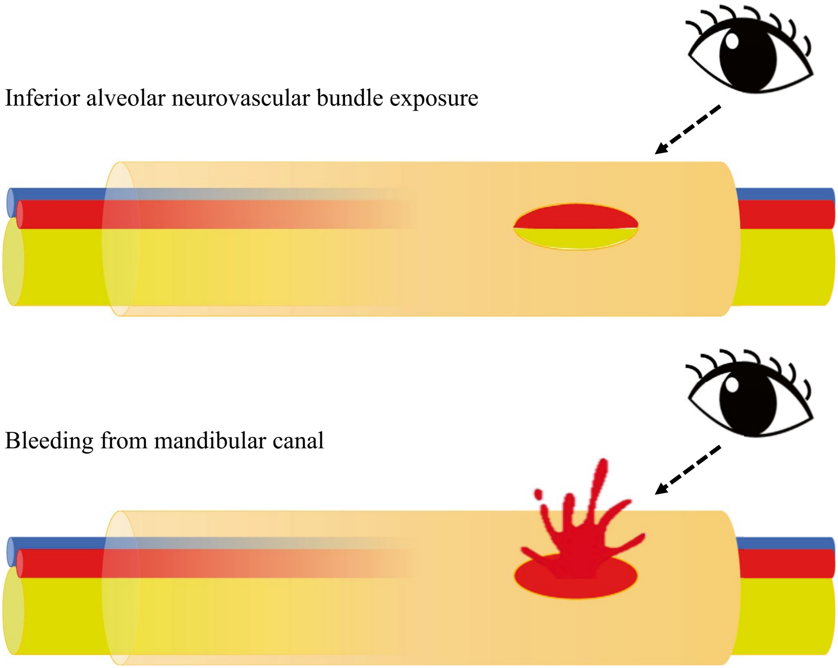


Fig. 7.5 Schematic diagram of intraoperative mandibular canal exposure

IAN Injury and Extraction Technique

Besides anatomical risk factors, IAN injuries can occur at any step of the extraction process. Risk factors for extraction procedures include transmission anaesthesia, alveolar bone removal, burs during crown resection, and pressure of tooth dislocation. Surgical techniques such as crown resection can significantly reduce the incidence of IAN injury (Jain et al. 2016). In contrast, it has been reported that crown resection using rotating instruments is associated with IAN injury (Gülicher and Gerlach 2001). The vertical resection of the root did not significantly increase the incidence of IAN injury, although there was a trend towards it (Valmaseda-Castellón et al. 2001). Crown resection does not appear to be a significant factor in IAN damage, as the instruments used during crown resection rarely injure the mandibular canal directly unless the crown lies on the mandibular canal. To prevent contact between the bur and the mandibular canal, the relationship between the crown and mandibular canal should be checked preoperatively by CBCT. Blindly splitting the crown when the tip of the bur is not visible should be avoided (Fig. 7.6). Thus, rotating instruments can cause IAN injury by accidental contact. Therefore, ultrasound bone-cutting equipment has been increasingly used in recent years. Ultrasound bone cutting devices do not damage soft tissues even if the cutting edge is accidentally brought into contact (Schlee et al. 2006). The meta-analysis results showed no

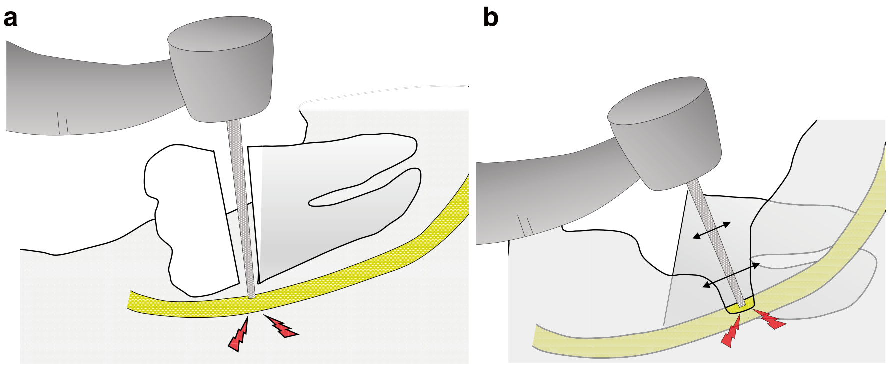


Fig. 7.6 Image of direct IAN injury when using a rotary cutting instrument. (**a**) Crown sectioning, (**b**) Bone removal

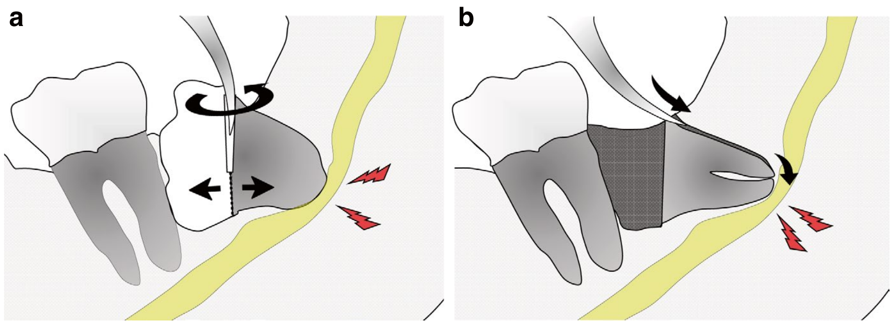


Fig. 7.7 Image of IAN compression by root of the mandibular third molar. The IAN can be compressed by the root due to inappropriate technique. (**a**) excessive force when dividing, (**b**) excessive force when pushing

significant difference in reducing neurological complications with the use of ultrasonic bone cutting instruments compared to rotating instruments although the number of data is still small (Cicciù et al. 2021).

Other factors include direct nerve compression by root displacement into the canal by the dental elevator (Qi et al. 2019) (Fig. 7.7). In advance, the relationship between the mandibular third molar and the mandibular canal can be ascertained with CBCT images, and the force vector applied to the tooth should be simulated. In addition, to avoid compression of the mandibular canal, it is necessary to avoid pushing the tooth root and secure space around the root through bone reduction. However, there are reports that the incidence of IAN injury is higher when bone removal is used with tooth sectioning (Kang et al. 2019). Therefore, coronectomy may be chosen to prevent IAN injury for the mandibular third molars close contact with the IAN (Long et al. 2012). Monaco et al. (2015) present a protocol for the coronectomy procedure and its usefulness, and we believe it should be considered as a means of avoiding IAN injury (Monaco et al. 2015). In coronectomy, root

migration averaged 2–3 mm by 6 months postoperatively, and root migration was significantly correlated with factors such as younger patients, females, and conical roots (Martin et al. 2015).

The relationship between the incidence of IAN injury and the surgeon's experience has also been found: in 6738 extractions from six studies, the prevalence of IAN injury was predominantly higher in trainees (2.3%) than in senior specialists (0.9%) (Kang et al. 2019).

After Sensory Deficit

Sensory deficit affects the patient's quality of life, and it is important to understand not only the risk factors but also the treatment options. There are many interventions and treatments, both surgical and non-surgical, that can be used to treat neuropathy. Coulthard et al. (2014) reviewed the iatrogenic inferior alveolar and lingual nerve injuries (Coulthard et al. 2014). A flowchart is shown as a reference for diagnosis when nerve injury occurs (Fig. 7.8). If IAN injury is suspected after a tooth extraction, it is important to evaluate the cause and extent of the damage. A variety of tests are used to evaluate neuropathy. Common tests include the 10-point visual analogue scale (VAS), static two-point discrimination, pain testing with a pain meter, static tactile threshold testing with filaments (Semmes-Weinstein monofilaments), and thermal perception testing with a thermotester. The sensory potential recorded from the nerve after stimulating the nerve is known as sensory nerve action potential (SNAP), and SNAP is performed as an objective test of perceptual impairment (Teerijoki-Oksa et al. 2003; Jääskeläinen 2004).

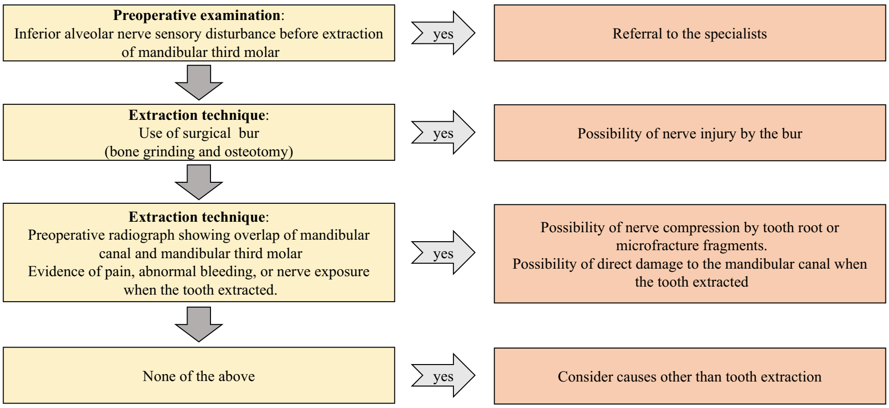


Fig. 7.8 Flowchart to identify the cause of inferior alveolar nerve injury (after Noma et al., 2001)

Treatment of Nerve Injury

When IAN injury occurs, there are two main types of treatment: conservative treatment and surgical treatment. Conservative treatment includes medication (Goldberg et al. 2017), stellate ganglion blocks (SGB) (Nogami and Taniguchi 2015), and physical therapy (far infrared laser, hot compress), while surgical intervention includes nerve repair surgery. If it is neuropraxia such as partial exposure of nerve fibres or contact only, medication and observation are the treatment choice. In this case, recovery might be expected with a couple of weeks to a month. If perceptual disturbance is observed, it is recommended to start oral administration of ATP/vitamin B12 as soon as possible (within two days after surgery). It is also recommended that if there is no improvement after 2 weeks of pharmacotherapy, SGB should be considered (Hasegawa et al. 2018).

However, if the nerve involvement is significant and the damage is greater than an axonal tear (axonotmesis) or nerve fibre tear (neurotmesis), spontaneous healing cannot be expected, so interventional treatment is required. Surgical treatments can be divided into two categories: those that touch the nerve fibres and those that do not (Fig. 7.9). Treatments that do not directly touch the nerve fibres include nerve decompression and scar removal (Mozsary and Syers 1985; Bagheri et al. 2012). Treatments that directly touch the nerve fibres include nerve suturing, grafting, and nerve regeneration induction (Cornelius et al. 1997; Jones 2010; Kim et al. 2011; Bagheri et al. 2012). Among these, decompression and neurorrhaphy of the damaged nerve are considered the best surgical treatments (Kushnerev and Yates 2015). Nerve grafting and regenerative guidance techniques are chosen when direct suturing is difficult. Nerve grafting is used in areas of flexion or for distance defects. In such cases, a donor nerve from another site is required, and the sural nerve and great auricular nerve have been used (Kushnerev and Yates 2015). Bagheri et al. (2012) recommend the use of the great auricular nerve, but recommend the sural nerve if the gap is greater than 20 mm (Bagheri et al. 2012). In contrast, the use of the great

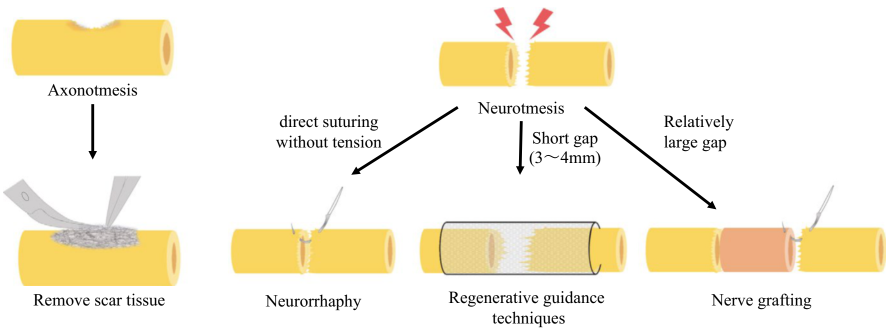


Fig. 7.9 Types of surgical treatments for nerve repair and their schematic diagrams. Decompression and scar removal are performed when there is pressure from scar tissue caused by nerve damage. If there is a nerve rupture, neurorrhaphy, regenerative guidance techniques, and nerve grafting may be indicated

auricular nerve, which requires only one incision, is also being studied, and further improvements in implantation techniques are expected (Iwanaga et al. 2019). Microsurgical nerve repair involves removal of the buccal cortical bone, which has also been shown to increase the inferior alveolar neurovascular bundle mobility (Kikuta et al. 2019). Surgical nerve repairs using the microsurgical technique have been relatively effective, with some showing significant neurosensory improvement in 92.9% of patients (Strauss et al. 2006). Bagheri et al. (2012) found that 81.7% of 152 patients with IAN injuries regained an acceptable level of functional sensory recovery (FSR) within 1 year after surgery (Bagheri et al. 2012). Besides, there was a negative correlation between the acquisition of FSR and the time to repair, and the success rate also decreases predominantly from the 12th month after injury (Bagheri et al. 2012). In other reports, 100% of patients who underwent reconstructive surgery within 90 days of injury showed improvement in neurological deficits, while the improvement rate decreased to 77% for patients who were injured for more than 90 days (Zuniga 2015). Therefore, it is important to perform the appropriate tests and properly understand the pathophysiology. Kushnerev has proposed a rough algorithm for treatment of nerve injury and suggests that 90 days should be considered as a benchmark for surgery if there is no improvement in neurological symptoms after injury (Kushnerev and Yates 2015).

Conclusions

In this chapter, IAN injury caused by mandibular third molar extraction is described by discussing each of the known risk factors. The extraction of the mandibular third molar is a routine procedure recommended when pericoronitis of the mandibular third molar occurs frequently. However, IAN injury may occur when extracting a mandibular third molar near the MC. If IAN injury occurs, the patient may experience daily unpleasant symptoms such as paraesthesia. The surgeon should be aware of this possibility and understand the risk factors for IAN injury. In particular, the surgeon should understand the anatomy and the characteristics of radiographs and CBCT images, so that they can choose the procedure and explain it to the patient in consideration of the risk factors (Iwanaga et al. 2021). In the unfortunate event of nerve injury, it is necessary to understand treatment methods beforehand so that patient explanations and responses can be made.

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8 Mandibular Third Molar Extraction and Lingual Nerve Injury

Katsuhisa Matsuo, Shogo Kikuta, and Joe Iwanaga

Introduction

Lingual nerve (LN) injury is one of the most severe complications in mandibular third molar extraction (Kushnerev and Yates 2015; Grossi et al. 2007). LN injury can significantly alter the patients' quality of life.

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Anatomy of the Lingual Nerve

Innervation

The LN supplies afferent general sensory fibres to the lingual gingiva, mucosa of the floor of the mouth, and mucosa of the anterior two-thirds of the tongue (Heasman and Beynon 1986; Zur et al. 2004). In the pterygomandibular space (a part of the infratemporal fossa), the LN receives the chorda tympani which is derived from the facial nerve and innervates the anterior two-thirds of the tongue for taste (Kikuta et al. 2019). The sublingual gland is innervated by the sublingual branch of the lingual nerve which synapses in the submandibular ganglion, and this ganglion is suspended from the lingual nerve.

Course of the Lingual Nerve before Entering the Floor of the Oral Cavity

The LN arises from the posterior division of the mandibular nerve (CN V3) below the foramen ovale in the infratemporal fossa (Joo et al. 2013), runs anteromedial with the inferior alveolar nerve (IAN) at the level of the mandibular foramen (Iwanaga et al. 2018a), and passes inferior to the mandibular attachment of the superior pharyngeal constrictor muscle. Then, the LN runs adjacent to the lingual cortical plate in the mandibular third molar area. The position of the LN varies significantly in each person (Pogrel et al. 1995).

Location of the Lingual Nerve in the Third Molar Area

Several studies have examined the location of the LN. Behnia et al. (2000) studied the course of 669 LNs and found that in the mandibular third molar region, the LN was in contact with the lingual plate in 22.3% and above and below the lingual crest in 14.1% and 85.8%, respectively. The mean horizontal and vertical distances from the LN to the lingual cortical plate and the lingual crest were 2.06 mm and 3.01 mm, respectively. According to Kiesselbach and Chamberlain (1984), 62% (out of 34 LNs) of the LNs in the mandibular third molar region were in contact with the lingual plate, and 17.6% were located level of or above the alveolar crest. The mean vertical and horizontal distances from the lingual plate and alveolar crest were 2.28 mm and 0.58 mm, respectively. In one case, the LN passed through the retromolar pad 2 mm above the lingual plate. Previous studies have shown the position of the LN in the absence of tongue movement but not in the presence of tongue movement. Iwanaga (2017) demonstrated that the LN course could change due to tongue movement in fresh frozen cadavers. When the tongue protrudes and turns to the contralateral side, the LN has a higher position than when in a neutral and low tongue position (see Fig. 10 in Chap. 1). In addition, the relative course of the LN is also affected by the alveolar bone resorption and the attachment of the mylohyoid muscle onto the mandible.

Diameter of the Lingual Nerve

Various measurements of the diameter of the LN have been reported. Hölzle and Wolff (2001) wrote that the diameter was 2.7 ± 0.3 mm (range, 1.9–3.6 mm) in 68 specimens, and Kim et al. (2004) found this diameter to be 3.3 ± 0.6 mm (range, 2.2–4.4 mm) in 32 specimens. In a recent study, Kikuta et al. (2019) measured the diameter of the LN using fresh frozen cadavers and reported that the diameter of the lingual nerve was different compared to formalin-fixed cadavers. Hölzle and Wolff (2001), by comparing the shape of the LN in formalin-fixed and fresh cadavers, concluded that the effect of formalin fixation on the shape of the LN was minimum. On the other hand, Iwanaga et al. (2018a) discussed the possibility of a statistically significant difference in the mean diameter of the LN between fresh frozen and formalin-fixed cadavers due to nerve compression by the medial pterygoid muscle and mandibular ramus. Pippi et al. (2017) reported the results of previous measurements for the average diameter of the LN and the average horizontal and vertical distances between the lingual nerve and the lingual cortical plate of the mandibular third molar region. These results are summarized in Table 8.1.

Table 8.1 Lingual nerve location in lower third molar region

Study	Nerves	Horizontal distance (mm)	Vertical distance (mm)	Mandibular bone contact, %	At level of or above Mandibular Crest, %	Mean diameter (mm)
Kiesselbach and Chamberlain (1984)	34	0.59 ± 0.90	2.28 ± 1.96	62	17.6	1.86
Pogrel et al. (1995)	40	3.45 ± 1.48	8.32 ± 4.05	0	15	3.62
Miloro et al. (1997)	20	2.53 ± 0.67	2.75 ± 0.97	25	10	2.54
Behnia et al. (2000)	669	2.06 ± 1.10	3.01 ± 0.42	23.27	14.05	–
Hölzle and Wolff (2001)	68	0.86 ± 1.00	7.83 ± 1.65	57.4	8.82	2.7
Kim et al. (2004)	32	–	–	–	–	3.3
Karakas et al. (2007)	21	4.19 ± 1.99	9.56 ± 5.28	0	4.7	2.56 ± 0.59
Erdogmus et al. (2008)	42	9.3 ± 2.1	7.06 ± 1.3	0	0	2.04 ± 0.4
Mendes et al. (2013)	24	4.40 ± 2.4	16.8 ± 5.7	0	0	–
Dias et al. (2015)	46	0.57 ± 0.56	9.15 ± 3.87	26	7	–
Kikuta et al. (2019)	20	–	–	–	–	2.20

Epidemiology of Lingual Nerve Injury

Incidence

The incidence of LN injury has been reported in numerous papers. A large prospective study in 2010 reported that out of 4338 mandibular third molar extractions performed by surgeons of various levels, temporary LN injury occurred in 0.69% and permanent LN injury in 0.16% (Cheung et al. 2010). Jerjes et al. (2010) reported that temporary LN injury occurred in 1.8% and permanent LN injury occurred in 1.1%. Table 8.2 summarizes the incidence of LN injury (Pippi et al. 2017) (Table 8.2). The results in this table show that temporary LN damage ranges from 0% to 37.5%, and permanent LN damage ranges from 0% to 2.63%.

Sex

Some reports indicate that male patients have a significantly higher incidence of permanent LN paraesthesia (Jerjes et al. 2010; Tay and Go 2004), while others suggest that females have a higher incidence of LN injury and that the patient's jaw and mouth opening may be related to the LN injury (Tojyo et al. 2019). However, Cheung et al. (2010) reported no association between the patient's sex and the risk of inferior alveolar nerve or LN injury. Thus, the difference between sexes in LN injury is still controversial.

Age

Valmaseda-Castellón et al. (2000) reported that there was no relationship between age and the LN injury. However, the relationship between aging and the risk of LN damage has been discussed in many studies (Chiapasco et al. 1993; Gülicher and Gerlach 2001; Renton and McGurk 2001). Root completion, bone hardening, ankylosed teeth, presence of infection, and loss of tissue elasticity are some examples of age-related changes in the jawbone (Kandasamy et al. 2009). These changes in the bone and surrounding soft tissues might be involved in the LN injury.

Local and General Anaesthesia

It has been reported that procedures under general anaesthesia have a higher risk of LN injury than those under local anaesthesia (Gülicher and Gerlach 2001). Brann et al. (1999) reported that, regardless of the difficulty of the surgery or the sedation, the incidence of LN injury is more than five times higher when third molars are removed under general anaesthesia than local anaesthesia. The possible reasons can be patient positioning, mucosal and periosteal dissection, and bone removal. In addition, conscious patients tend to send a series of signs, such as complaints of

Table 8.2 Incidence and various risk factors of lingual nerve injury

Author (1970 ~ 2015)	Study type	Surgical method	Anaesthesia	Bone removal	Sample size (Teeth)	LN deficit(%) Temporary	Permanent	Risk factor of the LN injury (only risk factors that were statistically significant are listed)
Rud (1970)	PS	LST	L	C,D	718	0.83	0.14	ND
Rood (1983)	PS	LST	G	C,D	1400	6.64	0	ND
Hochwald et al. (1983)	PS	LST	L + G	C	598	4.3	0	No statistically significant correlation
Rud (1984)	PS	LST	G	C	609	3	0	No statistically significant correlation
Goldberg et al. (1985)	PS	BA	L + G	D	500	0.6	0.2	ND
Wofford and Miller (1987)	PS	BA	L	D	576	0.71	0.17	ND
Mason (1988)	PS	BA+LF	G	C,D	747	8.3	0.4	Depth of impaction, removal of overhanging distal bone, lingual flap retraction, operating time
		LST			293	19.8	1.02	
Obiechina (1990)	PS	BA	L	NS	367	0.27	0	ND
Carmichael and McGowan (1992)	PS	BA+LF	L + G	C,D	1339	15	0.6	Complete bone cover, horizontal and others (Winter's classification), lingual flap retraction
Rood (1992)	PS	BA+LF	G	C,D	406	3.2	2	Lingual split technique, bone removal with bur
		LST			384	12.8	0	
Schultze-Mosgua and Reich (1993)	PS	BA+LF	L	D	791	1.9	0	ND
Walters (1995)	PS	LST	G	C	1000	0.5	0	ND
Robinson and Smith (1996b)	PS	BA+LF	L + G	D	378	6.08	0.79	Lingual flap retraction
		BA			393	0.51	0.25	
Appiah-Anane and Appiah-Anane (1997)	PS	BA	L	D	504	0.2	0	ND
Moss and Wake (1999)	RS	LST	G	C	2088	0.8	0	ND
Gargallo-Albiol et al. (2000)	PS	BA+LF	L	D	142	2.11	0	ND
		BA			158	0.63	0	
Bataineh (2001)	PS	BA+LF L	L	D	741	2.6	0	Lingual flap retraction
Guicher and Gerlach (2001)	PS	BA+LF	L + G	D	1106	2.1	0.37	General anaesthesia, experience of the operator, shape of roots, sectioning/osteotomy in the depth of socket

(continued)

Table 8.2 (continued)

Author (1970 ~ 2015)	Study type	Surgical method	Anaesthesia	Bone removal	Sample size (Teeth)	LN deficit(%) Temporary	LN deficit(%) Permanent	Risk factor of the LN injury (only risk factors that were statistically significant are listed)
Gomes et al. (2005)	RCT	BA	L + G	D	55	0	0	Lingual flap retraction
		BA+LF			55	9.1	0	
Jerjes et al. (2006)	PS	BA	L	NS	1087	5.52	1	Experience of the operator
Baqain et al. (2010)	PS	BA	L	D	299	0.3	0	Lingual flap retraction, bleeding into the socket
		BA+LF			110	9.1	0	
Natt Janakiraman et al. (2010)	PS	BA	NS	NS	119	4.2	1.7	No statistically significant correlation
Jerjes et al. (2010)	PS	BA	L	NS	3236	0.62	1.1	Male patients, distoangular impactions, horizontal impaction, partially erupted, experience of the operator,
								Close radiographic proximity to the inferior alveolar canal
Lata and Tiwari (2011)	PS	BA	L	D	90	5.5	1.1	ND
Charan-Babu et al. (2013)	PS	BA	L	D	92	1.1	0	Age of the patient above 26 years, lingual flap retraction, depth of impaction (≧10 mm), duration of surgery above 30 min
		BA+LF			8	37.5	0	
Guerrouani et al. (2013)	RS	BA	G	D	7659	1.8	0	ND
Smith (2013)	PS	BA	L + G	D	1455	0.14	0.07	ND
		BA+LF			134	1.5	0	
Nguyen et al. (2014)	RS	BA	L + G	D	10,160	0.069	0.079	No statistically significant correlation
Yadav et al. (2014)	PS	BA	L	D	576	1.7	0.2	Lingual flap retraction, tooth sectioning
		BA+LF			624	9.1	0.5	
Shad et al. (2015)	RCT	BA	L	NS	190	2.1	0.52	Lingual flap retraction
		BA+LF			190		8.94	0

BA buccal approach, *C* chisel, *D* drill, *L* local, *G* general, *LF* lingual flap, *LN* lingual nerve, *LST* lingual split technique, *NS* not specified, *PS* prospective study, *RCT* randomized controlled trial, *RS* retrospective study
ND not described

pain, that limit the surgeon's soft tissue retraction and surgical force (Brann et al. 1999).

Depth of the Third Molar

Radiographic imaging evaluation is important to assess the depth of the mandibular third molar. One of the imaging methods for evaluating the difficulty of mandibular third molar extraction is Winter's (WAR) line reported by George Winter in 1926 (Renton et al. 2001) (Fig. 8.1). Charan Babu et al. (2013) stated that more deeply impacted mandibular third molars require more bone removal, making tooth removal more complicated. If the Winter's red line is 10 mm or more, it may lead to LN injury. Two other studies have also reported that the deeper the mandibular third molar, the higher the rate of LN damage (Carmichael and McGowan 1992; Mason 1988). In contrast, some studies concluded that the depth of impaction was not clearly associated with LN injury. Vertical impactions had a significantly lower incidence, whereas those classified as horizontal or "other" impactions had a significantly higher incidence of LN injury (Carmichael and McGowan 1992). Paradoxically, fully erupted mandibular third molars had the highest rate of LN injury (5.4%). Indeed, erupted mandibular third molars subjected to surgical removal were often difficult cases requiring such procedures as lingual flap retraction, ostectomy, and tooth sectioning. The erupted tooth has no protection by the tongue from surgical invasion of, for example, the lingual cortical bone, although the impacted third molar usually has. These surgical manoeuvres seem to be the true cause of the LN injury, not the depth of impaction (Valmaseda-Castellón et al. 2000).

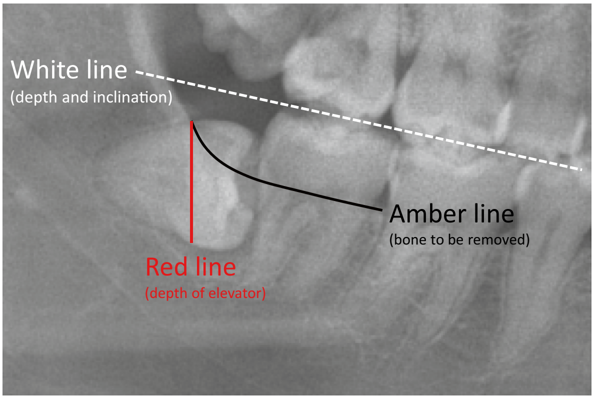


Fig. 8.1 A white line is drawn along the occlusal surface of the erupted mandibular molars (depth and inclination). The amber line shows the surface of the bone distal to the third molar to the top of the interdental septum between the first and second molars (amount of alveolar bone to be removed). The red line is grated vertically from the amber line to the depth at which the elevator should be applied; the deeper the line, the more complex the removal of the third molar

Angulation of the Third Molar and Thickness of the Lingual Plate

Thinning and perforation of the lingual cortical plate can decrease the distance between the LN and mandibular third molar and therefore might increase the risk of LN injury (Renton and McGurk 2001; Tolstunov et al. 2016). Valmaseda-Castellón et al. (2000) reported that mandibular third molars with lingual angulation were associated with LN injury. It is recommended to confirm the tooth axis and thickness of the lingual cortical plate with images before the procedure.

Difficulty by Classification and Lingual Nerve Injury

Amorim Gomes et al. (2005) reported that patients with LN injury were more commonly a Pell and Gregory Class II, Position C (Pell and Gregory 1933). The high incidence of LN injury in Position C may be that the more profound the depth of impaction, the more difficult it is to remove the tooth, as described in the depth of the mandibular third molar. Distoangular impaction has been reported to have the highest incidence of LN injury in Winter's classification (Cheung et al. 2010; Juodzbalys and Daugela 2013). Tojyo et al. (2019) concluded that the distally angulated mandibular third molar may have a higher risk of LN injury as the crown position of the mandibular third molar could anatomically be closer to the LN. Meanwhile, there was a report that horizontal impaction was the most common cause of LN injury (Carmichael and McGowan 1992). In many previous studies, it is concluded that the surgeon's experience is an important factor for preventing LN injury (Cheung et al. 2010; Jerjes et al. 2006).

Surgical Techniques to Avoid Lingual Nerve Injury

Surgical Procedure

There are various approaches for removing mandibular third molars, including the buccal approach, a buccal approach with lingual flap retraction, and a lingual split technique. Pippi et al. (2017) analysed a number of papers and demonstrated that temporary LN injury was significantly higher with the buccal approach with lingual flap retraction than with the buccal approach and considerably higher with the lingual split technique than with the buccal approach with lingual flap retraction. Jerjes et al. (2010) reported that by minimizing lingual soft tissue interference during mandibular third molar surgery, the incidence of LN injury is lower than using a lingual flap. Table 8.2 shows that the lingual flap retractor was the most common factor of LN injury.

Incision

To avoid LN injury, it is essential to understand its anatomical landmarks. Pippi et al. (2017) reported that the distal release incision for mandibular third molar removal should not be directed lingual to the ascending ramus of the mandible but should be inclined vestibular at 45° to the distal surface of the mandibular third molar. Some researchers have reported the abnormal course of the LN as "passing through the retromolar pad" and "in the retromolar pad just on the surface of the mandible," but these are rare (Behnia et al. 2000; Kiesselbach and Chamberlain 1984). Recently, it was found that the lingual nerve passes deep to the retromolar pad, but never "pass through the retromolar pad" based on anatomical findings and using the definition of the retromolar pad as lying under the retromolar glands (Iwanaga et al. 2018b, 2020) (Fig. 8.2). A distal incision for the mandibular third molar extraction should not be made posterior to the last molar but posterolaterally on the bone surface, never going posteriorly where it is not underlined by bone.

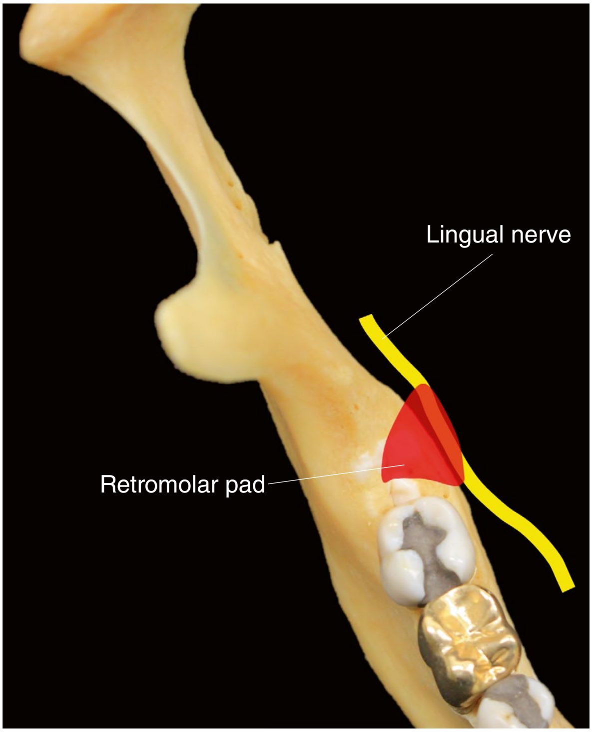


Fig. 8.2 Lingual nerve and retromolar pad

Crown Sectioning

As mentioned above, the lingual nerve is nearby or in contact with the lingual plate of the mandibular third molar, and this area is likely to be damaged during crown division. Yadav et al. (2014) reported a highly significant correlation between temporary LN injury and tooth division. Renton et al. (2001) reported that lingual plate perforation and LN exposure are the main risk factors for LN injury during mandibular third molar removal. Based on these results, great care should be taken to avoid drilling the lingual bone during crown division in preventing LN injury.

Suture

The relationship between the suture and the LN injury has been rarely discussed. According to Chossegros et al. (2002), it is safe to insert the needle tip approximately 3 mm from the gingival margin of the lingual flap, if needed (Chossegros et al. 2002). However, there is no exact "safe" distance as the LN course is variable.

What To Do After Lingual Nerve Injury (Treatment)

Skill in repairing the LN is important for oral surgeons, as its injury dramatically affects the quality of life of patients. There are two types of treatment for lingual nerve injury, conservative and surgical treatments. Conservative treatment includes pharmacotherapy, physiotherapy, and stellate ganglion block. Some patients may recover spontaneously. However, if conservative treatment is not effective, surgical intervention should be considered (Verweij et al. 2017). Surgical treatment has been the mainstream treatment for nerve damage associated with mandibular third molar surgery for many years (Leung 2019). Direct end-to-end suture of the torn nerve ends without tension is recommended for LN repair (Fujita et al. 2014). Direct suture with minimal tension is necessary for nerve regeneration and functional sensory recovery (Kushnerev and Yates 2015). Although the overall success rates of LN repair is reported at over 75%, the taste has a poor rate of recovery since the gustatory fibres (carried by the chorda tympani) make up a small portion of the LN and have a slight chance of reconnecting with an appropriate endoneural sheath (Robinson and Smith 1996a). Significant defects of the LN necessitate an autogenous nerve graft (e.g., great auricular nerve, sural nerve) or collagen conduit. Regeneration times for these procedures are longer than in cases treated with direct sutures, and recovery might be accompanied by continuous pain for a longer period of time (Fujita et al. 2014). Currently, there is no clear consensus on the optimal timing for treating the LN after its injury, but past reports strongly suggest that surgery should be considered 90 days after injury if there is no improvement in sensation (Kushnerev and Yates 2015; Zuniga 2015).

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9 Haemorrhage and Pseudoaneurysm Following Extraction of the Third Molar

Yosuke Harazono

Introduction

Third molar extraction is one of the most common dentoalveolar surgical operations in adult population. Kunkel et al. (2007) reported postoperative haemorrhage in 1 out of 100 cases requiring hospitalization due to severe third molar complications. A large retrospective analysis of complications associated with third molar surgeries reported prolonged haemorrhage in 0.16% to 5.8% of patients (Chiapasco et al. 1993; Muhonen et al. 1997; Moghadam and Caminiti 2002; Bui et al. 2003; Benazzou et al. 2009). Unexpected haemorrhage is more often recognized as an intraoperative complication (0.80%) rather than a postoperative complication (0.15%) (Chuang et al. 2007).

Systemic Factors

General conditions with coagulation disorder, platelet disorder, vascular hyperpermeability, and excessive fibrinolysis have been suggested as possible causes of haemorrhage from extraction sites (Campos et al. 2019). Compared to healthy individuals, patients with thrombocytopenic purpura, von Willebrand disease, haemophilia, leukaemia, liver cirrhosis, and diabetes and patients undergoing anticoagulant therapy for cardiovascular disease are more likely to develop post-extraction bleeding. However, most intraoperative or postoperative bleeding problems are due to local factors rather than coagulopathies (Raymond et al. 2008). Residual inflammatory granulation tissue in the extraction socket is a main factor of local causes. Other factors include crushing and damage of soft tissues around the extraction socket,

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mechanical irritation of soft tissue due to sharp edges of bone, the fracture of alveolar or mandibular bone, intraosseous or extraosseous blood vessel damage, presence of aneurysm or haemangiomas, inadequate suturing, and excessive gargling. If there is a history of previous extractions with no persistent haemorrhage, a local source should be identified and treated.

Local Factors

Responsible blood vessels of haemorrhage include the inferior alveolar artery (IAA), sublingual artery (SLA) (or its branch), lingual branch of the IAA, buccal artery (or its branch), facial artery (or its branch), the artery in the retromolar foramen (RMF), and other intraosseous accessory vessels (Fig. 9.1). Bleeding from the root canal occasionally disturbs the surgical field although it should not be a major haemorrhage. Intravenous bleeding from each accompanying vein also occurs. IAA damage can occur during bone removal, crown/root splitting, or luxation of root. The injury to the SLA or lingual branch of the IAA may occur in the case of lingual dislocation of third molar teeth fragment or thinning of the lingual cortical bone. Damage to the facial or buccal artery is associated with the initial mucosal incision and detachment of the periosteum. A recent study by Takeshita et al. revealed that the facial artery is at a risk of injury during the mandibular third molar extraction as the artery courses approximately 2 mm lateral to the buccal cortical plate in the third molar crown area (Takeshita et al. 2021). The artery in the retromolar canal (RMC), which branches off in the mandibular canal, bifurcates into facial and buccal branches after exiting the RMF (Iwanaga et al. 2016). Injury

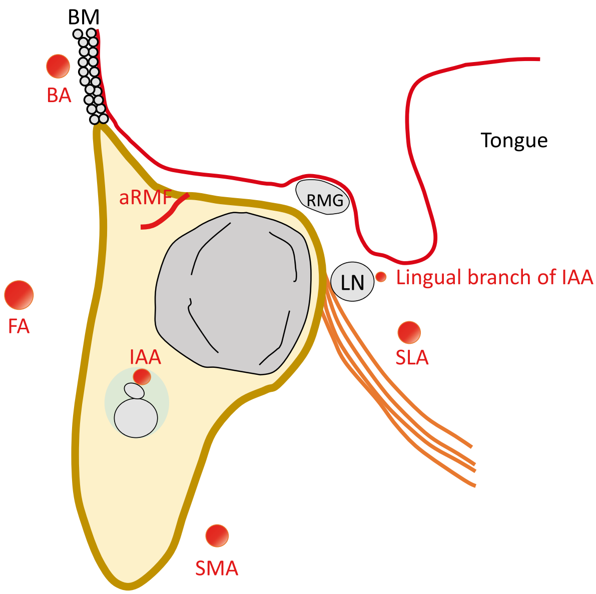


Fig. 9.1 Responsible blood vessels of haemorrhage in the mandibular third molar area. aRMF, artery in the retromolar foramen; BA, buccal artery; BM, buccinator muscle; FA, facial artery; IAA, inferior alveolar artery; LN, lingual nerve; RMG, retromolar gland; SLA, sublingual artery; SMA, submental artery

Table 9.1 Surgical process and responsible arteries of bleeding

Surgical process	Responsible arteries of bleeding						
	Inferior alveolar artery (IAA)	Sublingual artery	Lingual branch of IAA	Facial artery	Buccal artery	Artery in retromolar foramen	Intraosseous accessory vessels
Incision, detachment of periosteum				Yes	Yes	Yes	Yes
Bone removal	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Crown/root splitting	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Luxation of root	Yes					Yes	Yes
Lingual dislocation of tooth fragment/ perforation of lingual cortical plate		Yes	Yes			Yes	Yes

to this artery should be careful in bone removal around third molar which can be visible on CBCT preoperatively (Fukami et al. 2012; Truong et al. 2017). Other intraosseous accessory vessels can be injured anytime during the procedure. Although chances of serious bleeding are relatively rare, understanding the potential source of bleeding might help operators when they encounter an unexpected haemorrhage (Table 9.1).

Management of Haemorrhage

The algorithm for management of acute intraoral haemorrhage has been reported (Moghadam and Caminiti 2002; Raymond et al. 2008). If the bleeding lasts for 30 or 60 min, after the patient is anaesthetized, any clots should be removed by curetting the socket, and the source should be identified. Bleeding from bone within the socket can be controlled with crushing of the source with an instrument, placing bone wax, or cauterizing the site. If an arterial bleeding point is identified, it should be ligated or cauterized. The surgical site should be resutured, and any persistent local oozing can be treated with the application of haemostatic agents, such as absorbable gelatin sponges, oxidized regenerated cellulose, microfibrillar collagen, absorbable collagen dressings, or topical thrombin applied to some of these agents (Table 9.2) (Pereira et al. 2018; Campos et al. 2019). Emergency cases necessitate examination with angiography and treatment with embolization (Benazzou et al. 2009).

Table 9.2 Commercial name and types of some biosurgical agents (after Pereira et al. 2018)

Commercial name	Topical haemostatic	Mechanism of action
Surgicel Original®, Surgicel Nu-Knit®	Oxidized regenerated cellulose	Physical matrix for initiation of the clot
Surgicel Fibrillar®, Interceed®, Gelitacel®		The low pH promotes antimicrobial effect
Surgifoam®, Gelfoam®, Gelfilm®	Gelatins	Physical matrix for initiation of the clot
Gelita-spon®, Geli putty®		
Floseal®, Surgiflo®	Gelatine + thrombin	Combination of effects of gelatin and thrombin
Instat®, Helitene®, Helistat®, Avitene®	Microfibrillar collagen	Platelet adhesion and activation
Avitene flour®, Avitene Ultrafoam®		
EndoAvitene®, Avitene Ultrawrap®		
Evicel®, Tisseal®, Crosseal®, Quixil®	Fibrin sealants	Thrombin and fibrinogen are combined at the time of application. Thrombin degrades fibrinogen into fibrin, forming clot
Evithrom®, Recothrom®, Thrombin-JMI®	Topical thrombin	Converts fibrinogen into fibrin to form clot
		Promotes activation of coagulation factor
BioGlue®	Glutaraldehyde and bovine	Glutaraldehyde interacts with bovine albumin
	albumin adhesive	and protein cell at wound site to form a resistant matrix
Dermabond®, Omnex®	Cyanoacrylate adhesives	Liquid monomers form polymers in the presence of water and glue two surfaces
CoSeal®	Polyethylene glycol	Two polyethylene glycol polymers mix and react at wound site

Pseudoaneurysm

Pseudoaneurysm is a false aneurysm that occurs at the site of arterial injury. Pseudoaneurysm is an extravascular haematoma that communicates with the intravascular space and does not contain any layer of the vessel wall unlike a true aneurysm. The vascular wall is composed of fibrous connective tissue from fibrin/platelet crosslinks that develops following rupture of the endothelium. Therefore, the wall is much weaker than that of true aneurysms (Rich and Spencer 1978; Philip et al. 2021). On the other hand, arteriovenous malformations are anatomical risk factors, causing life-threatening haemorrhage and pseudoaneurysm (Kruizinga et al. 2007; Bouloux et al. 2009; Idle et al. 2013). The most common clinical

presentation of a pseudoaneurysm is a femoral artery pseudoaneurysm with access for endovascular procedures, followed by visceral pseudoaneurysms and aortic pseudoaneurysms.

Pseudoaneurysms usually occur at 1 to 8 weeks after damage to a blood vessel (Marco et al. 2008). Contrast-enhanced CT and angiography are the most useful and essential in diagnosing a pseudoaneurysm (Yeo et al. 2012). A peripheral organized haematoma can be observed surrounding the central contrast-enhanced arterial lumen. CT angiography can adequately triage patients in need of endovascular and surgical treatment. In addition, it can assess the patency and position of the trunk and distal branches of the external carotid artery and delineate the true size of the pseudoaneurysm, including the degree of thrombosis.

Pseudoaneurysm Caused by Oral and Maxillofacial Surgery

An extraction procedure for third molar sometimes causes arterial bleeding. Injury to the trunk or branch of artery during extraction can produce pseudoaneurysm (Figs. 9.2 and 9.3). There are several reports about the pseudoaneurysm in oral and maxillofacial surgery including removal of the molars (Maeda et al. 2007; Rayati et al. 2010; Rawat et al. 2019; Stiefel et al. 2010), Le Fort I osteotomy (Hemmig et al. 1987), intraoral vertical ramus osteotomy (Fujisawa et al. 2002), and sagittal split ramus osteotomy (Precious et al. 2012). Furthermore, to search for cases with haemorrhage and pseudoaneurysm after third molar removal, which were treated by embolization, between 1990 and 2020, we used PubMed with the following key words: "hemorrhage", "embolization", "extraction", and "third molar". Patients with possible causes such as arteriovenous malformation were excluded. Eleven cases (eight males, three females) in seven references were identified by the above method, and three other cases (two males, one female) were added from three Japanese articles (Table 9.3). The mean age was 34.3 years (range 20 to 71 years), and the duration from extraction of the third molar to the bleeding ranged from intraoperative to 8 weeks. The most common bleeding point was the IAA, and n-butyl cyanoacrylate (NBCA) was most frequently used as an embolic material.

Treatment for these lesions includes various surgical and endovascular options. Transcatheter embolization is considered a safe, quick, and effective technique that avoids extensive surgical procedures (Figs. 9.4 and 9.5). Embolization materials can be classified according to their physical properties (fluids, particulates, and mechanical devices), the size of the vessels in which they are used (central or peripheral), and the occlusion duration (permanent or temporary) (Benazzou et al. 2009). Numerous agents have been used for the embolization therapy such as metallic coils, polyvinyl alcohol (PVA) particles, NBCA, polymers (Onyx, SQUID), and absorbable sponge gel (Pandyan et al. 2014; Rawat et al. 2019).



Fig. 9.2 Dental panoramic tomography shows the left impacted mandibular third molar

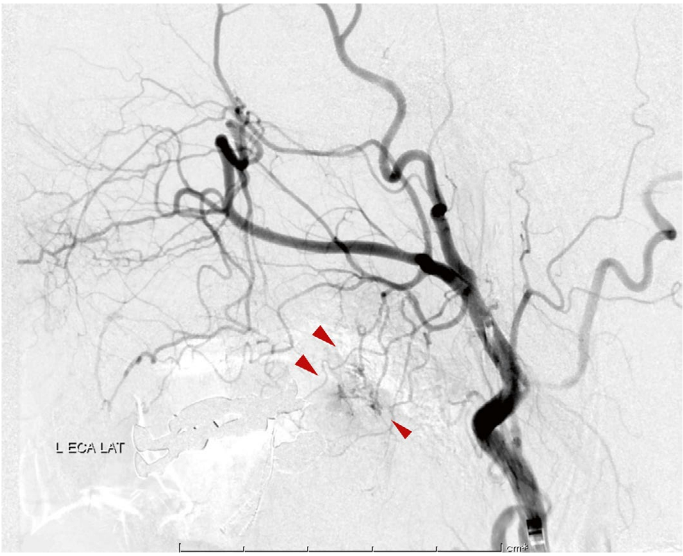


Fig. 9.3 Angiography of the left external carotid artery before embolization reveals a pseudoaneurysm (arrowheads) in the branch of the inferior alveolar artery

Table 9.3 Reported haemorrhage cases after third molar removal treated by embolization

Case	Age	Sex	Teeth	Duration from extraction	Bleeding point	Embolic materials	Reference
1	25	M	Lower left	3 days	FA branch	33% NBCA-lipiodol	Marco et al. (2008)
2	71	M	Upper left	1 hour	PSAA	Coil	Benazzou et al. (2009)
3	20	M	Lower left	2 weeks	FA branch	Coil, polymers	Pukenas et al. (2012)
4	60	M	Lower left	Intraoperative	IAA, FA	PVA particles, gelatin, 25% NBCA-lipiodol	Wasson et al. (2012)
5	24	M	Lower left	5 weeks	IAA branch	33% NBCA-lipiodol	Sagara et al. (2013)
6	37	F	Lower left	1 week	IAA trunk	33% NBCA-lipiodol	
7	29	M	Lower right	3 days	IAA branch	25% NBCA-lipiodol	
8	24	F	Lower right	1 week	IAA branch	25% NBCA-lipiodol	
9	26	M	Upper right	2 hours	PSAA trunk	Coil, 33% NBCA–lipiodol	
10	47	F	Lower right	4 days	IAA branch	Coil	Bianchi et al. (2016)
11	24	M	Upper right	1 week	MA branch	25% NBCA-lipiodol	Rawat et al. (2019)
12	21	M	Upper right	Within operative date	PSAA	Coil, gelatin	Sakamoto et al. (1991)
13	48	F	Lower right	4 days	IAA	Coil	Koga et al. (2005)
14	24	M	Lower left	8 weeks	IAA branch	33% NBCA-lipiodol	Kono et al. (2012)
Mean	34.286						

FA facial artery, *IAA* inferior alveolar artery, *MA* maxillary artery, *NBCA* n-butyl-2-cyanoacrylate, *PSAA* posterior superior alveolar artery

Few dental treatments can cause life-threatening complications. However, some complications due to dental extraction, including haemorrhage and pseudoaneurysm, can result in deaths if not diagnosed and treated quickly. Careful surgical techniques, planning, knowledge of surgical anatomy, and awareness of surgical complications are ways to prevent serious complications. Moreover, it should always be kept in mind that for patients with severe bleeding/pseudoaneurysm after third molar extraction, the most immediate risk is dyspnoea due to airway obstruction.



Fig. 9.4 Dental panoramic tomography after embolization. Note that the surgical clip is seen near the left mandibular notch (arrowhead)



Fig. 9.5 Angiography of the left external carotid artery after embolization shows disappearance of the pseudoaneurysm

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Displacement of the Mandibular Third Molar in the Submandibular/Sublingual Space

10

Masanori Masui and Joe Iwanaga

Introduction

Accidental displacement of the tooth fragment in the anatomical space is one of the unfavourable surgical complications of the mandibular third molar extraction, which has been reported in English literature since Doran (1932) reported the first case (Fig. 10.1). Reported number of the cases are relatively small; however, the actual number should be larger as we empirically know that the patient who's mandibular third molar is displaced in the floor of the mouth during the extraction is

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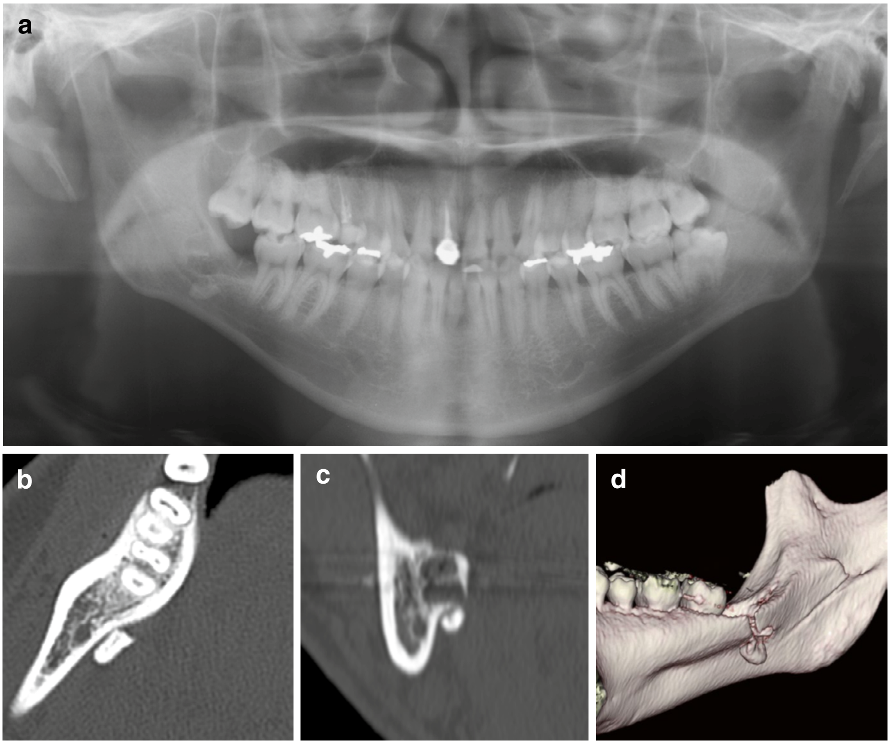


Fig. 10.1 Panoramic radiogram and computed tomographic (CT) images of the displacement of the mandibular third molar in the submandibular space. (**a**) Panoramic radiogram, (**b**) CT axial view, (**c**) CT coronal view, (**d**) 3D reconstructed CT image

occasionally referred to the hospital. The anatomical spaces around the mandibular third molar include submandibular space, sublingual space, pterygomandibular space, and parapharyngeal space that connect with the retropharyngeal space. Among these, displacement in the submandibular/sublingual space has been the most frequently reported (Fig. 10.2) (Cheung et al. 2010).

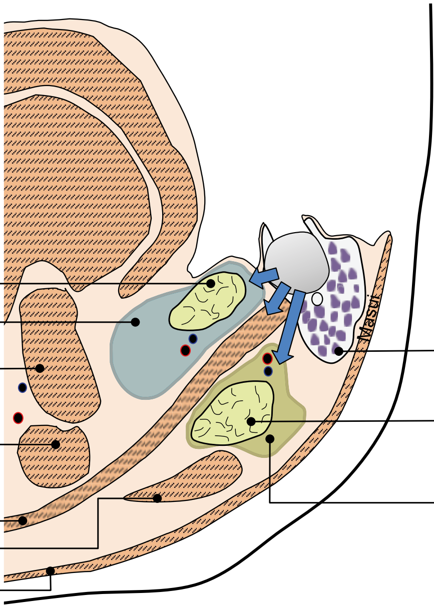


Fig. 10.2 Anatomical structure around the submandibular/sublingual space. The arrows indicate the direction of the displaced fragment, from top to bottom: the sublingual space, in the mylohyoid muscle, and the submandibular space

Anatomical Structure Around the Submandibular/ Sublingual Space

The sublingual space is a loose connective tissue surrounded by the hyoglossus and genioglossus muscles on the medial side, the mylohyoid muscle inferiorly, the mandible anteriorly and laterally, and the mucosa of the floor of the mouth superiorly. The sublingual space includes the lingual nerve, sublingual artery/nerve, sublingual gland, major sublingual duct (Bartholin's duct), minor sublingual ducts (ducts of Rivinus), deep part (superior part) of the submandibular gland, and submandibular duct (Wharton's duct) as the main structures (Fig. 10.3). The submandibular space is bordered by the mylohyoid muscle superomedially, the investing layer of the deep cervical fascia and platysma inferolaterally, and the mandible superolaterally. The submandibular space includes the submandibular lymph nodes, facial artery and vein, submental artery, and nerve to the mylohyoid muscle. Generally, the sublingual and submandibular spaces communicate at the posterior edge of the mylohyoid muscle. However, the mylohyoid muscle has a posterior defect in 27.3–77%, where the sublingual gland and the submental vessels can traverse (Nathan and Luchansky 1985, White et al. 2001, Harrison et al. 2013, Nakajima et al. 2014). Thus, the sublingual space also communicates with the submandibular space through the defect. In the literature, the term "displacement into the submandibular space or sublingual

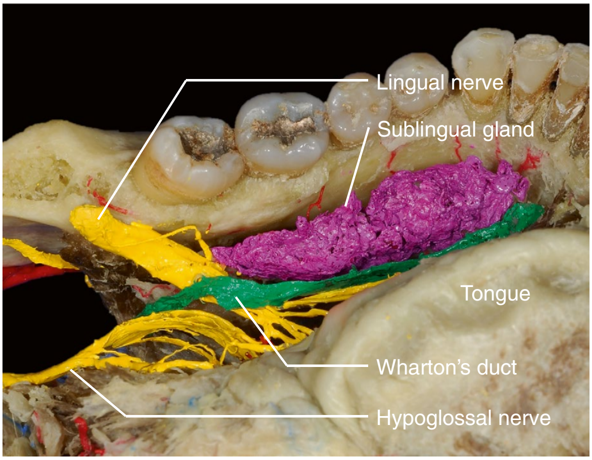


Fig. 10.3 Cadaveric image of the sublingual space showing the lingual nerve, hypoglossal nerve, sublingual gland, and Wharton's duct

space" is generally used to localize the fragment although the exact location of the fragment (whether in the sublingual or submandibular space) is often unclear even after retrieval. Given consideration, Masui et al. (2021) suggested that it might be better to describe "displacement into the floor of the mouth" instead of "displacement into the sublingual space or submandibular space."

The Causes of Displacement of the Mandibular Third Molar

The causes of accidental displacement of the mandibular third molar during extraction can be categorized into two groups, i.e. iatrogenic factors and anatomical (patient's) factors (Table 10.1).

Iatrogenic Factors

Unnecessary excessive forces from the buccal side might lead displacement of the mandibular third molar, in which a sufficient surgical field cannot be visualized due to inadequate bone removal or unexpected/uncontrolled bleeding, followed by inadequate range of surgical field, inappropriate use of surgical instruments, and incorrect techniques and lack of anatomical knowledge. These are all caused by insufficient training or unintentional human error which can be prevented.

Anatomical (Patient's) Factors

The depth of the third molar and thickness of the lingual cortical plate can be good predictors of the displacement. Also, the fracture of the lingual cortical plate and age of the patient (e.g. before root formation is completed) are other risk factors.

Table 10.1 Risk factors of the displacement (Chubb et al. 2021)

Surgeon's factors	Anatomical (patient's) factors
Unnecessary excessive forces	The depth of impacted mandibular third molar
Inadequate clinical/radiological diagnosis Inadequate range of surgical field Inappropriate use of surgical instruments	The lingual cortical bone perforation/thinning Fracture of the lingual cortical plate
Incorrect techniques and lack of anatomical knowledge	Age

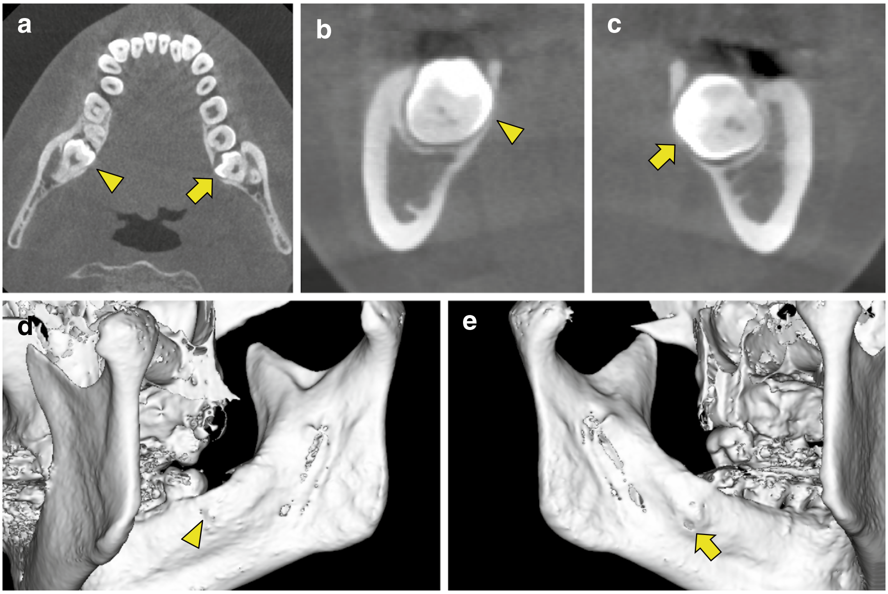


Fig. 10.4 CBCT images of lingual cortical bone perforating/thinning compared to the surrounding cortical bone due to the mandibular third molar in the same patient. Axial image of the right (arrowheads) and left (arrows) mandibular third molars. The lingual cortical bone is thinning on the right side (**b**) and perforating on the left side (**c**). The 3D reconstructed CT images show the defect of lingual cortical bone on the left side only (**d**, **e**). The triangle indicates thinning of the bone and arrow indicates perforating of the bone

Computed tomographic (CT) images show a case in which the lingual cortical bone of the mandibular third molar is defective/thinned compared to the surrounding cortical bone (Fig. 10.4). Amin et al. (2020) reported the incidence of pre-existing lingual cortex perforation before removal of the mandibular third molar using cone beam CT (CBCT). The incidence of the perforation was 51.2% at the level of root apex and 52.8% at most lingual portion on the apical half of the root. In addition, the mean thickness of the lingual bone to the root was 1.25 mm around the root apex and 0.93 mm around the most lingual portion on the apical half of the root, which most frequent lingual cortex shape was the "undercut" shape (Amin et al. 2020). Around 2.5% of human dry mandibles had small perforations in the

lingual cortical bone around the mandibular third molar area (Stacy and Orth 1964). Therefore, preoperative CT or CBCT diagnosis is recommended to evaluate the perforation or the thickness of the lingual cortical bone, which is considered important to avoid displacement into the submandibular/sublingual space.

Diagnosis

Immediate retrieval of the fragment with insufficient skill or lack of anatomical knowledge may push the fragment deeper or allow it to migrate to adjacent spaces. Therefore, it is important to accurately detect the location using preoperative images. The usefulness of multi detector CT (MDCT) or CBCT has been reported for localizing the displaced mandibular third molar in the submandibular/sublingual space (Huang et al. 2007; Varvara et al. 2016). However, CBCT is inferior for the visualization of soft tissues. In order to evaluate displaced fragment in the floor of the mouth, the positional relationship with the fragment and the mylohyoid muscle should be evaluated, i.e. superior or inferior to the mylohyoid muscle and anterior or posterior to the posterior edge of the mylohyoid muscle. In addition, there is a possibility of the fragment displaced within the mylohyoid muscle. Therefore, MDCT is considered more informative than CBCT to evaluate the position of fragments based on the positional relationship with the mylohyoid muscle.

Potential Complications/Events Caused by Displacement

Lingual Nerve Injury

The lingual nerve runs near the lingual cortical plate so that the lingual nerve injury may occur. There are several reports of lingual nerve injury due to displacement fragment (Varvara et al. 2016; Torul et al. 2017; Masui et al. 2021). Some cases might have fracture above the mylohyoid line and fragment displaced into the submandibular space. Given the running course and layer of the lingual nerve, the fragment could traverse the lingual nerve to reach below the mylohyoid muscle. This type of displacement might be a sign of "lingual nerve at risk" (Fig. 10.5).

Infection

Displaced fragment can be a cause of infection. Because there are anatomical spaces adjacent to the mandible, once the fragment gets infected, the infection can spread easily inside and outside the mandible. The incidence of delayed infection following the displaced fragment left in situ has not been reported yet. However, there is not enough evidence that can recommend surgeons to leave in situ so that the potentiality of infection cannot be ruled out, and careful follow-up is required when the fragment is left in situ.

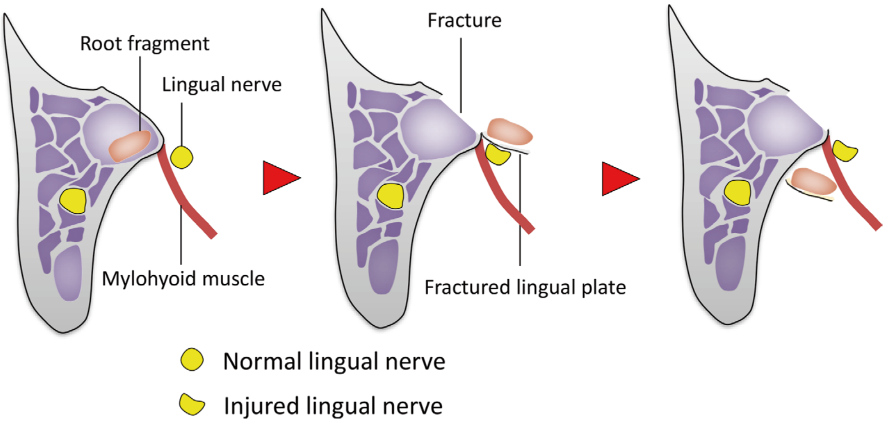


Fig. 10.5 Schematic drawing of a sign of lingual nerve injury

Migration

The prolonged displacement fragment may cause scarring of surrounding tissues and migration to deep tissues. The migration of the displaced fragment might be caused by inward traction by the mylohyoid muscle. In cases the lingual cortical bone is perforated, and the mylohyoid muscle is well developed, the mylohyoid muscle may directly contact the mandibular third molar. In addition, the displaced fragment fused with the lingual cortical bone can be retracted medially because of the mylohyoid muscle contraction. In these cases, the displaced fragment can easily migrate into the deeper tissue.

Retrieval or Leaving In Situ

In the literature, majority of the cases chose either immediate or delayed retrieval of the fragment, whereas Azar-Arasa et al. (2012) suggested that if the displaced fragment is small, surgical retrieval might not be necessary because it is usually asymptomatic. In addition, it may be difficult to find small fragments in the tissue. There is still no consensus if the displaced fragment or tooth needs to be removed or left in situ, as well as immediate or delayed retrieval has to be planned (Chubb et al. 2021). Some researchers agreed that the retrieval should be performed as soon as possible with systemic antibiotics administration (Di Nardo et al. 2019), especially if pain, trismus, and swelling are present (Brauer 2009). Delayed retrieval is mostly not recommended due to infectious aetiology (Nusrath and Banks 2010). Others considered the retrieval of the fragment is larger than 5 mm as this size is more likely to be symptomatic (Aznar-Arasa et al. 2012). If smaller than 5 mm, then conservative management should be considered initially because the fragment might be too small to be palpated or found within the soft tissues (Nusrath and Banks 2010; Aznar-Arasa et al. 2012; Chubb et al. 2021). However, the 5 mm theory is based on

the experience, and there is not enough evidence supporting it. In the recent study by the authors with six cases of retrieval, three cases underwent retrieval within 3 days, and the other three cases had delayed retrieval (15, 36, and 61 days). Delayed referral by primary dentists had resulted in delayed retrieval (Masui et al. 2021).

Surgical Approach

Intraoral, extraoral, and combined procedures have been reported. In general, the intraoral procedure is most commonly chosen (Huang et al. 2007).

Intraoral Approach (Fig. 10.6)

The anatomical structures to note in the intraoral procedure are the lingual nerve and Wharton's duct (see Fig. 10.3). It is desirable to check whether the fragment of mandibular third molar is palpable through the mucosa of the floor of the mouth and then determine the procedure by considering the horizontal distance from the lingual cortical bone by the diagnostic imaging findings.

There are two approaches to remove the fragment, the direct approach, and the lingual mucoperiosteal flap. The direct approach incises the mucosa right above the fragment. When the fragment is palpable and located horizontally away from lingual cortical bone, the direct approach might be chosen. However, in the lingual mucoperiosteal flap, an incision is made from the mandibular third molar to the first molar or the second premolar along the cervical margin, and the mucoperiosteal flap is made to remove the fragment. The mucoperiosteal flap is suitable for the cases in which the fragment is not palpable or located horizontally close to lingual cortical bone. If the fragment is located superficially, it can be sufficiently removed under local anaesthesia. However, if it is deeply located, the retrieval of fragment can be more challenging because of the severe gag reflex and movement of the patient, and the general anaesthesia may be indicated. The authors herein have suggested a decision tree for the intraoral approach (Fig. 10.7) (Masui et al. 2021).

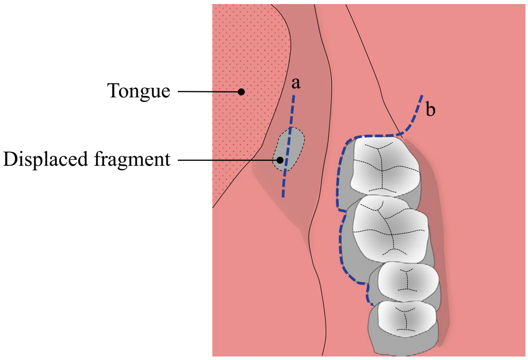


Fig. 10.6 Decision tree for approaching the techniques for tooth fragment removal

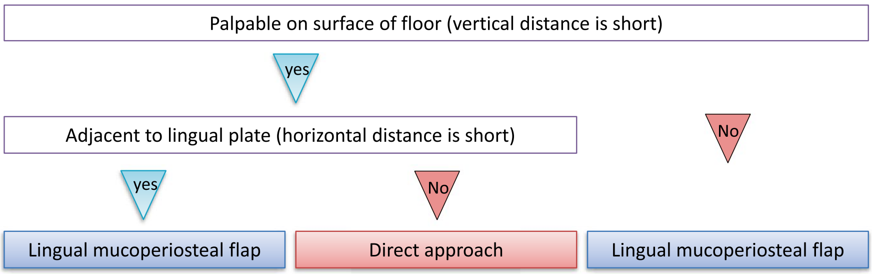


Fig. 10.7 Decision tree for the intraoral approach. Direct approach and lingual mucoperiosteal flap

Extraoral Approach

There are a few reports on the retrieval of fragment by an extraoral procedure (Adeyemi et al. 2016; Oliveira et al. 2019). Retrieval by submandibular approach provides a sufficient surgical field. However, it may cause damage to the marginal mandibular branch of the facial nerve and the lingual nerve. In addition, the scar by the skin incision may remain. It is extremely important to inform the surgical procedure to the patient preoperatively.

Lingual Nerve Injury Caused by Surgical Retrieval

If the displaced fragment is located in the submandibular space, it is feasible to avoid lingual nerve injury by the lingual mucoperiosteal flap. However, if the fragment displaced in the sublingual space, the lingual nerve may be exposed in the surgical field during retrieval, so there is a higher chance of lingual nerve injury.

According to Iwanaga et al. (2023), temporary, not permanent, lingual nerve impairment/injury caused by retrieval of displaced mandibular third molar fragment was 15.8% (6/38) of the retrieved cases which did not have LN impairment/injury before retrieval. The permanent iatrogenic LN impairment/injury due to retrieval of the dMTM is considered uncommon as long as the appropriate surgical approach is chosen based on the preoperative diagnosis and anatomical knowledge.

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Mandibular Third Molar Extraction and Fracture of the Mandible

11

Kisho Ono and Joe Iwanaga

Introduction

Mandibular fracture is a very rare but a serious complication associated with tooth extraction. Interestingly, mandibular angle fractures often include mandibular third molars on the fracture line, but the mandibular third molars are not always fully erupted but impacted in many cases. In addition, most of the mandibular third molars associated with fractures are not functioning. Conventionally, the teeth on the fracture line have been extracted in principle since these were prone to secondary infection and may be accompanied by osteomyelitis, resulting in bone union failure. However, there are reports that even if the teeth on the fracture line are

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preserved, there is no significant difference from the case that the teeth on the fracture line are extracted in the occurrence of postoperative complications. Sagittal split ramus osteotomy for jaw deformity, which is the most commonly used surgical orthodontic surgery, can also cause an unexpected fracture due to the presence of mandibular third molars.

In this chapter, we reviewed the mandibular fractures associated with the mandibular third molars and discuss potential risk factors and preventive measures.

Frequency of Mandibular Fractures Due to Mandibular Third Molar Extraction

Mandibular fractures associated with mandibular third molar extractions are extremely rare complications with an incidence of 0.0033 to 0.0036% intraoperatively (Wagner et al. 2005; Woldenberg et al. 2007; Alling and Alling 1993) and 0.0013 to 0.0046% postoperatively (Wagner et al. 2005; Woldenberg et al. 2007; Alling and Alling 1993; Perry and Goldberg 2000). Interestingly, intraoperative and postoperative mandibular fractures related to tooth removal (not limited to mandibular third molar) were reported as 25% and 75%, respectively (Joshi et al. 2016; Iwanaga et al. 2021). In literature review, almost all pathological mandibular fractures after tooth extraction were due to mandibular third molar extraction (Coletti and Ord 2008; Iizuka et al. 1997; Dunstan and Sugar 1997; Krimmel and Reinert 2000; Perry and Goldberg 2000; Libersa et al. 2002; Werkmeister et al. 2005; Wagner et al. 2005, 2007; Komerik and Karaduman 2006; Kunkel et al. 2007; Woldenberg et al. 2007; Khan et al. 2009; Valiati et al. 2009; Kao et al. 2010; Grau-Manclus et al. 2011; Cankaya et al. 2011). A meta-analysis of 47 reports conducted by Joshi et al. (2016) found 200 cases of iatrogenic mandible fracture related with any tooth removal during the period of 1953–2015. Out of those 200 cases, 75% were related to mandibular third molar extraction (Joshi et al. 2016; Iwanaga et al. 2021) (Fig. 11.1). These factors are associated with the unique characteristics of mandibular third molar extractions, which weaken the mandible by requiring higher

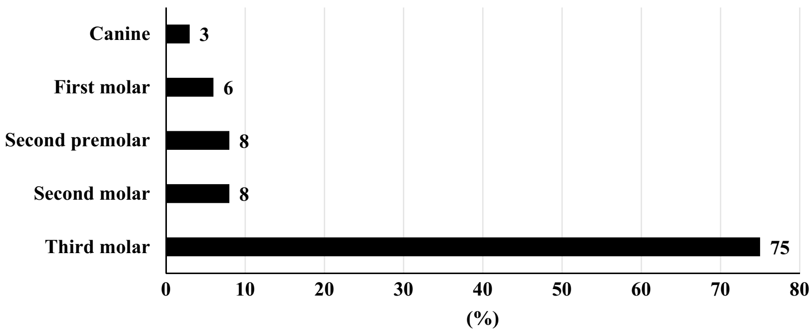


Fig. 11.1 Responsible tooth type that is associated with mandibular fractures during/after extraction

force or more extensive osteotomy than other tooth extractions (Boffano et al. 2010, 2012a, b; Boffano and Roccia 2010).

Technical Factors and Countermeasures for Intraoperative Mandibular Fractures during Mandibular Third Molar Extraction

Intraoperative mandibular fractures that occur during mandibular third molar extraction are generally accompanied by fracture noise and occlusal deviation (Wagner et al. 2005; Woldenberg et al. 2007; Alling and Alling 1993). Iizuka et al. (1997) argued that intraoperative fractures during tooth extraction were caused by misuse of instruments and improper stress on the bone. Tooth extraction using elevators is a procedure to dislocate the teeth utilizing the elasticity of the alveolar bone by wedge effect or wheel and axle effect, and it requires slow pressurization and no sudden force. In addition, mandibular fractures during mandibular third molar extraction might result from osteoporosis and aging, which reduces the amount of inorganic components and weakens the bone system (Iizuka et al. 1997; Krimmel and Reinert 2000). Iizuka et al. (1997) recommend that patients aged 40 years and older with mandibular third molars whose roots overlap the mandibular canal on X-ray should be placed in a high-risk group and tooth splitting should be done to minimize bone removal to prevent the mandible fractures.

Systemic and Local Factors of Mandibular Fractures Due to Third Molar Extraction

Wagner et al. (2005) reported that 82.4% (14 of 17) of cases were middle-aged older than 40 years regarding the predominant age of mandibular fractures due to third molar extraction. Similarly, 66.7% (8 of 12) of cases reported by Iizuka et al. (1997) and all 6 cases reported by Krimmel et al. were over 40 years old. This may be due to increasing amount of bone removal associated with age-related events, such as loss of mandibular elasticity, periodontal ligament narrowing, and mandibular third molar bone adhesions (Coletti and Ord 2008; Wagner et al. 2005; Kao et al. 2010). Furthermore, over the middle age, patients often have potential lesions in the mandible that can reduce the strength of the mandible, such as cystic lesions. In terms of gender, males have stronger occlusal force than females, so males are more likely to have postoperative mandibular fractures (Ethunandan et al. 2012). Therefore patients, specifically males over the age of 40 years, should be informed a risk of the mandible fractures following third molar extraction. Perry and Goldberg (2000) reported that 64.3% (18 of 28) of postoperative fractures had a history of pericoronitis, suggesting that bone demineralization due to chronic inflammation promoted bone weakening. Wagner et al. (2005) reported that left mandibular third molar extractions had a significantly higher frequency of mandibular fractures than right. The reason was that most of the surgeons were right-handed, so the left mandibular

Table 11.1 Risk and predisposing factors of mandibular fractures to be analysed during and after the removal of third molars

	Patient factors	Surgeon factors
During the operation	Age and gender (males over the age of 40 years)	Not well-planned treatment including osteotomies and odontosections
	Laterality (left > right)	Improper instrumentation
	Presence of third molar position of the third molar and space it occupies	Uncontrolled excessive force transmission to the bone
	Degree of impaction (occurred most frequently following removal of fully impacted teeth)	
	Pre-existing infection or bony lesions such as periodontal diseases, cysts and tumours, recurrent pericoronitis	
	Systemic disease or medications which may impair bone strength	
After the operation	Gender	
	Left or right side (right > left)	
	Chewing, biting hard food	
	Bruxism and/or clenching	
	Preoperative infections in the third molar site	
	Participation in sports	
	Injury due to assault or accident	

third molar had a poorer surgical field than the right one, and the amount of bone removed was large. We summarized risks and predisposing factors of mandibular fractures related to the removal of mandibular third molars in Table 11.1.

Correlation Between Impacted Mandibular Third Molar Condition and Mandibular Fracture

Before extraction of the mandibular impacted mandibular third molars, we can evaluate the position classification and impact type and angle of the mandibular third molars from the Pell and Gregory classification and Winter's classification (Pell and Gregory 1933; Winter 1929) and the difficulty level from the content of impacted teeth in the ramus of the mandible and the Pederson difficulty index (Pederson 1988; Iizuka et al. 1997) in the preoperative panoramic radiograph. The position of the impacted mandibular third molars in the mesio-distal direction is less important as a factor that causes mandibular fracture, and the vertical position is more important. In the Pell and Gregory classification, Position B (highest portion of the impacted mandibular third molar teeth is lower than the occlusal plane but above the cervical line of the second molar) and Position C (highest portion of the impacted mandibular third molar is lower than the cervical line of the second molar) increase the risk of

Table 11.2 Pederson difficulty index of extraction of impacted mandibular third molars

Classification	Value
Pell-Gregory's classification	
(1) depth	
Position A: High occlusal level	1
Position B: Medium occlusal level	2
Position C: Deep occlusal level	3
(2) ramus relationship/space available	
Class I: Sufficient space	1
Class II: Reduced space	2
Class III: No space	3
G.B. Winter's classification	
(3) spatial relationship	
Mesioangular	1
Horizontal/transverse	2
Vertical	3
Distoangular	4
Difficulty index (min 3, max 10)	(1) + (2) + (3)
Slightly difficult	3–4
Moderately difficult	5–6
Very difficult	7–10

mandible fractures. Besides, the higher the occupancy rate of the impacted tooth in the ramus of the mandible, the greater the amount of bone defect after tooth extraction, and the higher the risk of postoperative mandibular fracture. The Pederson difficulty index is a method for evaluating the difficulty of mandibular third molar extraction, which is quantified as a score of molar angulation according to Winter classification and impaction type according to Pell and Gregory classification (Pederson 1988; Iizuka et al. 1997) (Table 11.2). The higher the score, the higher the difficulty, and the greater the amount of bone removed during tooth extraction, making mandibular fractures more likely to occur (Woldenberg et al. 2007; Krimmel and Reinert 2000). Wagner et al. (2005) reported that the average Pederson difficulty index for patients with postoperative mandibular fractures was 7.8 ± 0.4 points. Mandible strength depends more on cortical bone than medulla (Meisami et al. 2002). Therefore, in the cases of mandibular third molar with complete or partial vertical impaction, the amount of bone removal of the cortical bone including the internal oblique ridge of mandible increases, and the resistance to stress such as the bite force and chewing power of the mandible decreases. Consequently, a complete postoperative mandible fracture may occur unintentionally. Joshi et al. (2016) analysed 138 cases of impacted teeth-related mandibular angle fractures of which 54% were full bony, 30% were partial bony, and 16% were soft tissue impaction (Fig. 11.2). In this way, when the evaluation of the difficulty of tooth extraction suggests the possibility of fracture, we should consider to evaluate using not only panoramic radiographs but also computed tomography (CT) imaging to visualize the three-dimensional mandibular morphology and expect residual bone thickness and width.

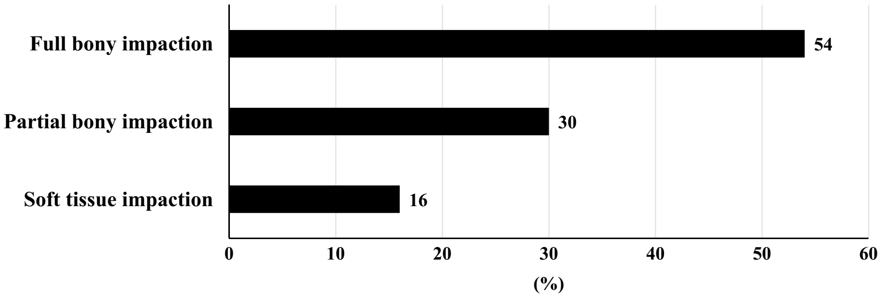


Fig. 11.2 Mandibular fracture frequency by impacted conditions (n = 138)

Countermeasures for Postoperative Mandibular Fractures After Third Molar Extraction

Fracture and Chewing

Postoperative mandible fractures are most frequent in the second and third weeks (Iizuka et al. 1997; Perry and Goldberg 2000; Libersa et al. 2002; Chrcanovic and Custódio 2010). It is thought that the cause is that the pain in the wound almost disappears at this time and the patients start normal chewing. This is accord with the time when the granulation tissue of the extraction socket is replaced with fibrotic connective tissue (Amler 1977). In this situation, excessive chewing power and relatively small trauma can contribute to the increased frequency of fractures. Interestingly, 71% of postoperative mandibular fractures after tooth extraction occurred during chewing (Perry and Goldberg 2000; Libersa et al. 2002; Komerik and Karaduman 2006; Kao et al. 2010; Grau-Manclus et al. 2011). Postoperative fractures have occurred, especially when chewing hard objects such as bagels, nuts, and steaks (Perry and Goldberg 2000). For that, it is recommended to continue eating soft food for about 2–4 weeks after tooth extraction for the risk group of postoperative mandibular fracture (Libersa et al. 2002). The clack sound during chewing is important as a sign that a postoperative mandibular fracture has occurred (Woldenberg et al. 2007; Krimmel and Reinert 2000). However, panoramic radiographs may not show fracture findings, which may delay diagnosis and treatment and cause osteomyelitis (Woldenberg et al. 2007) (Fig. 11.3).

Diagnosis of the Postoperative Fractures

The background of mandibular osteomyelitis after tooth extraction may be related to the presence of potential mandibular fractures (González-Navarro et al. 2017; Yamamoto et al. 2019). Diagnosis of postoperative fractures can be difficult, and only a few shows obvious malocclusion. If the first radiograph fails to reveal a high

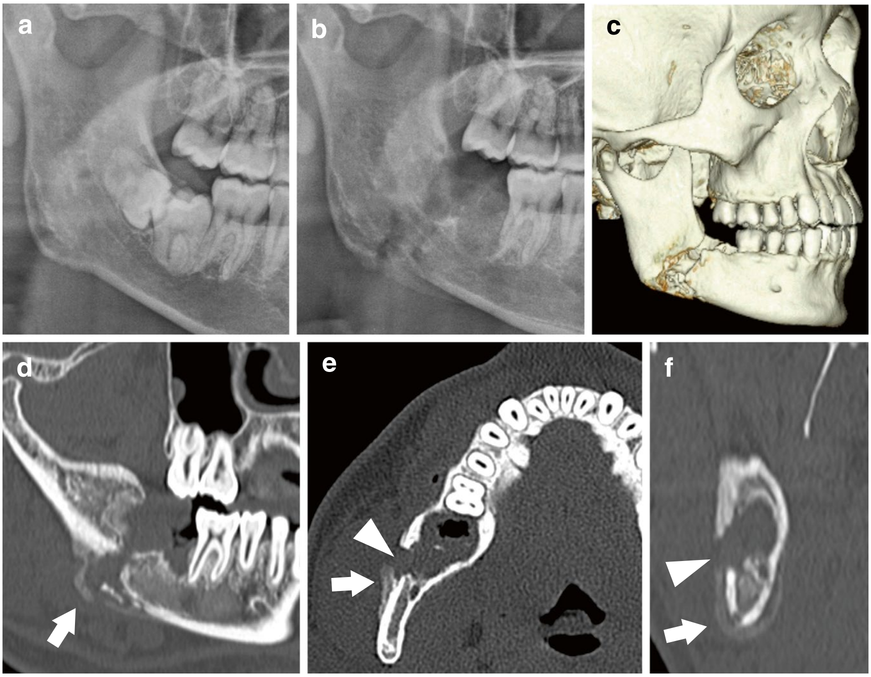


Fig. 11.3 A case of osteomyelitis after extraction of mandibular third molar. (**a**, **b**) Panorama X-ray images at before (**a**) and 2 months after (**b**) tooth extraction (**c**) 3D model constructed by CT images. (**d–f**) CT scan showing osteolysis in the right mandible. A rupture (arrowhead) and periosteal reaction (arrow) were found in the buccal cortical bone

suspicion index for the fracture despite the possibility of a postoperative fracture, we may have to repeat a few days later to visualize the fracture line (Komerik and Karaduman 2006; Chrcanovic and Custódio 2010). In addition to follow-up observations using panoramic radiographs, we should require detailed examination by CT if there are any potential finding of the fracture.

Relationship Between the Presence of Mandibular Third Molars and Mandibular Angle Fractures

Mandibular angle fractures are one of the most common mandibular fractures of the mandible because of their morphological features, i.e. the presence of mandibular third molars and concentration of the stress/external force (Fuselier et al., 2002). Several studies have shown that there is a direct relationship between the presence of impacted mandibular third molars and mandibular angle fractures, which increases risk of fracture two to three times (Safdar and Meechan 1995; Tevepaugh and Dodson 1995; Hammond et al. 2015). Teeth are involved in about 50% of mandibular fractures (Neal et al. 1978). Impacted mandibular third molars in the

mandibular angle area may be considered a risk factor for fractures in this area (Wolujewicz 1980). Based on these findings, some authors suggest early removal of the impacted mandibular third molars to prevent fractures of the mandibular angle (Hanson et al. 2004; Peterson et al. 2000; Schwimmer et al. 1983). On the other hand, prophylactic removal of mandibular third molar reduces the risk of mandibular angle fractures but might increase the risk of mandibular condyle fractures (Iida et al. 2004; Mehra et al. 2019; Tiwari et al. 2016; Xu et al. 2017; Samieirad et al. 2019).

Controversy of the Mandibular Third Molar Extraction on the Fracture Line

In mandibular angle fractures, the treatment of third molars on the fracture line often causes controversy. Ellis (2002) showed that 85% of 402 cases of the mandibular angle fractures contained third molars (Fig. 11.4).

Historically, it was empirically believed that mandibular third molar extraction should be done before the fixation because third molars on the fracture line could be a cause of infection and potential obstacles for healing as the teeth were considered damaged, or the pulp was more likely to be necrotic and infected (Bradley 1965; Rowe and Killey 1968). Irby (1979) stated that mandibular third molars on the fracture line, where there were exposed in the oral cavity, were susceptible to

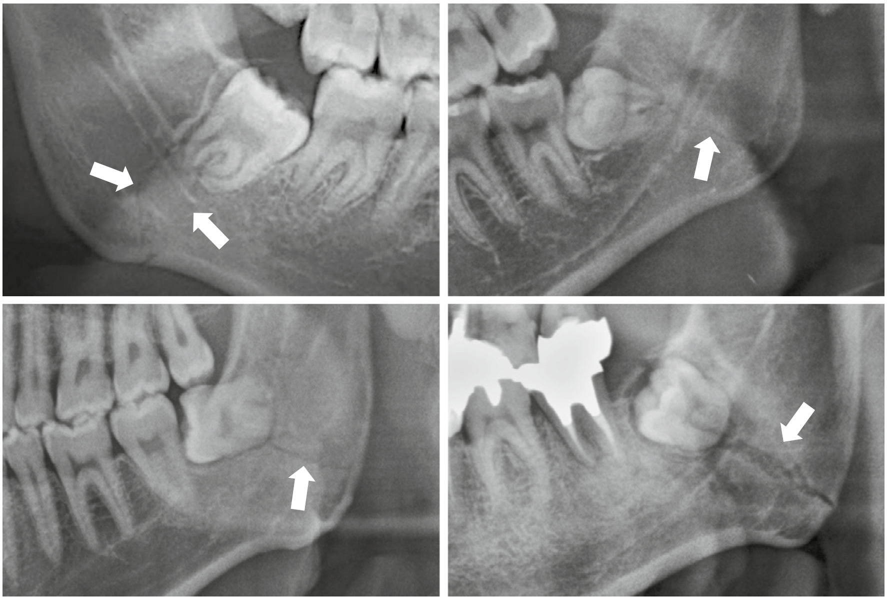


Fig. 11.4 Mandibular angle fractures with third molars on the fracture lines. The arrows indicate the fracture lines

reinfection and must be extracted because all fractures that penetrate this site cause further tissue damage and haematoma. However, recently, it became more controversial if the tooth extraction on the fracture line is necessary (Ellis 2002; Atanasov and Vuvakis 2000). Some researchers even enhanced that the teeth on the fracture line should be preserved because these can be useful for repairing the fracture, and conversely, removal of such teeth causes traumatic damage to the bone tissue (Yadavalli et al. 2011).

Interestingly, Ellis (2002) reported that the possibility of postoperative infections because of remaining third molars on the mandibular fracture line was 19.5%, close to 19.0% of the common probability of post-extraction infection. Chrcanovic (2012) said that intact teeth on the fracture line should be left in cases where there was no evidence of severe loosening or inflammatory changes, or there was no history of pericoronitis or periodontitis. In other words, if the teeth are not firmly fixed, the risk of infection increases when preserving teeth on the fracture line (Shetty and Freymiller 1989) (Fig. 11.5). Therefore, the method and duration of fixation of the fracture site are issues to be solved. By using the mini plate as a bone fixation device, we can obtain a more stable fixed force than the treatment by intermaxillary fixation alone, and the probability of infection reduces because the teeth on the fracture line can be sufficiently stable (Koury and Ellis 1992) (Fig. 11.6).

Since the mandibular third molars on the fracture line are rarely involved in occlusion and the conditions are different from those on the fracture line at other sites, treatment varies depending on the surgeon. On the other hand, Spiessl (1989) enumerated the following problems caused by extracting mandibular third molars on the fracture lines: turning a closed fracture into an open fracture, eliminating the possibility of inserting a fixation plate, and losing the bone as an abutment. Yamamoto et al. (2015) stated that it was beneficial to extract the mandibular third molars at the time of fixed plate removal after healing of the mandibular fracture to avoid serious complications (Fig. 11.7). We summarize the various reports in the literature that support extraction or preservation of the third molars on the fracture line in Table 11.3.

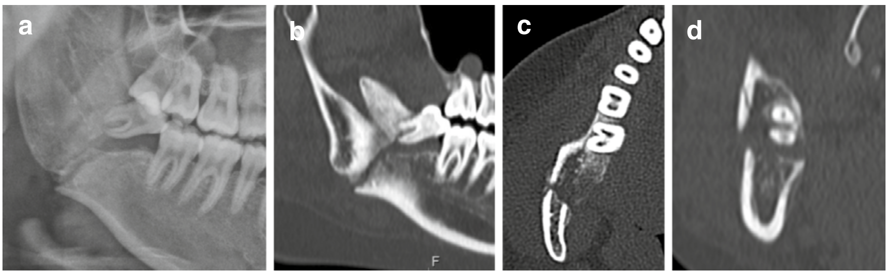


Fig. 11.5 A case of untreated old mandibular angle fracture causing infection around the mandibular third molar. (**a**–**d**) Panorama X-ray and CT images showing mandibular and third molar condition at first visit

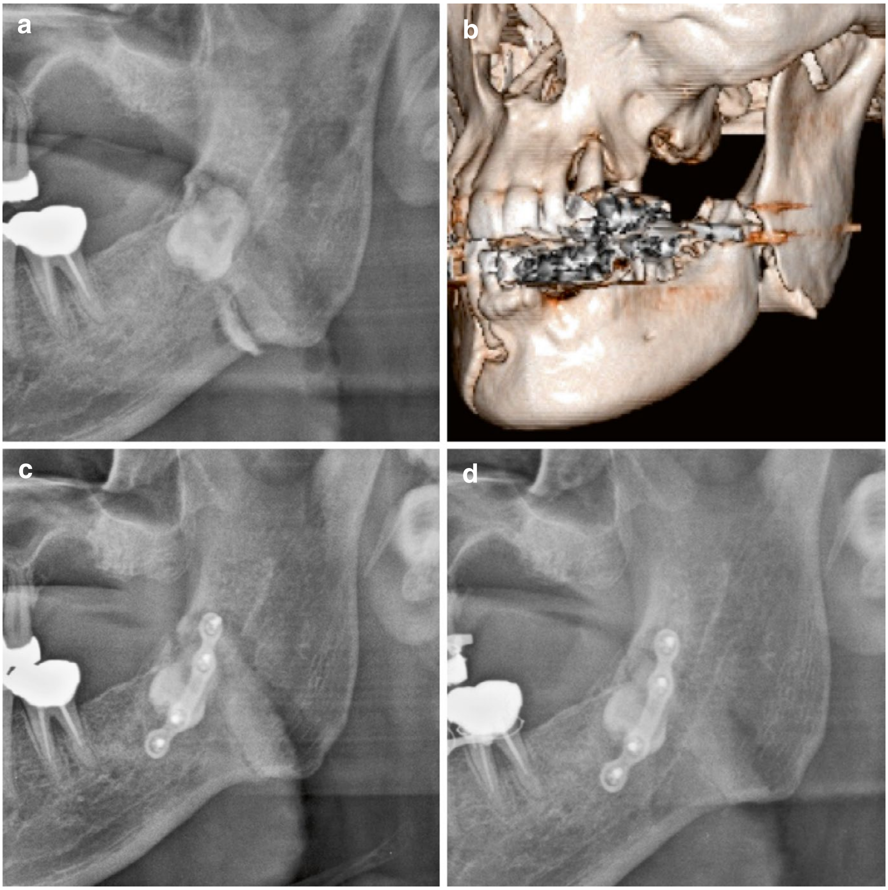


Fig. 11.6 A case of mandibular angle fracture with open reduction and internal fixation (ORIF) while preserving the impacted mandibular third molar on the fracture line. (**a**, **b**) Panorama X-ray image (**a**) and before (**a**) and 3D model (**b**) constructed by CT images at first visit. (**c**, **d**) Panorama X-ray images immediately (**c**) and 3 months (**d**) after ORIF

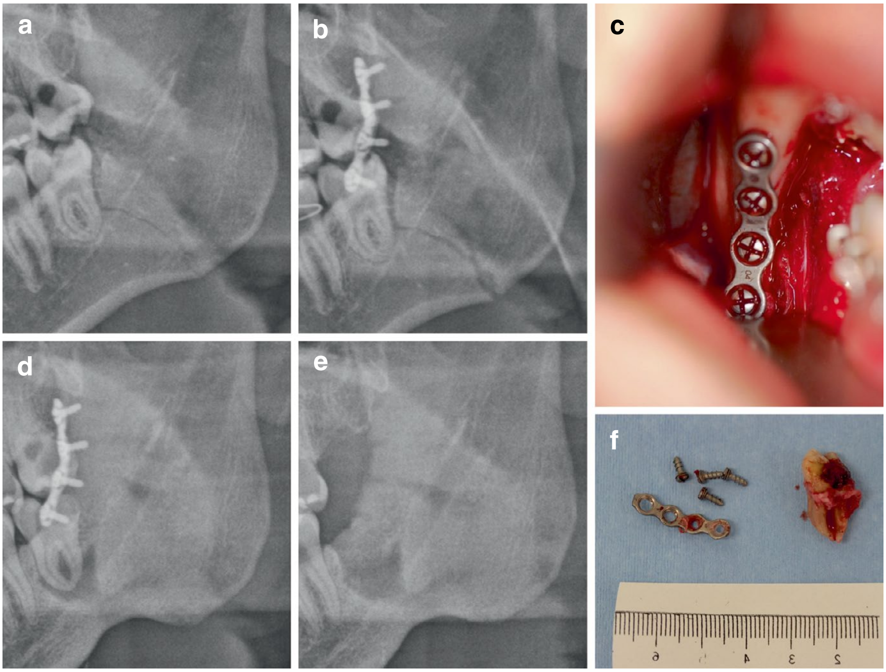


Fig. 11.7 A case of mandibular angle fracture in which the third molar on the fracture line was extracted at the same time as the fixation plate was removed. (**a**, **b**) Panorama X-ray images showing mandible and third molar condition at first visit (a) and immediately after ORIF (**b**). (**c**) Intraoperative photo at ORIF. (**d**) Panorama X-ray images showing follow-up at 4 years after ORIF. (**e**) Panorama X-ray images showing immediately after removing the fixed plate and mandibular third molar. (**f**) Removed mini plate, screws, and mandibular third molar

Unfavourable Mandibular Fracture Led by Sagittal Split Ramus Osteotomy Due to Mandibular Third Molar

Sagittal split ramus osteotomy (SSRO) is one of the most common surgical procedures for jaw deformities (Steenen and Becking 2016; Wang et al. 2016). Trauner and Obwegeser (1957) first introduced this procedure, and Hunsuck (1968), Dal Pont (1961), and Epker (1977) have improved it to avoid postoperative complications. However, this procedure still has complications (Aarabi et al. 2014; Camargo et al. 2015; Mensink et al. 2013). In particular, an unwanted intraoperative fracture called "bad split" occurs in association with the presence of mandibular third molars and osteogenesis imperfecta of the posterior trigone after mandibular third molar removal, besides problems such as surgeon's mistakes during operation and improper use of osteotomy instruments (Mensink et al. 2013; Steenen and Becking 2016; Eshghpour et al. 2021). Bad splits are irregular fractures of mandibles in an inappropriate position during osteotomy (Aarabi et al. 2014; Mensink et al. 2013;

Table 11.3 Summary of various literature that support extraction or preservation of the third molars on the fracture line

Literature supporting preservation of the teeth on the fracture line	
Spiessl (1989)	Reduce the risk of turning a closed fracture into an open fracture
Spiessl (1989), Koury and Ellis (1992), Fox and Kellman (2003), Yadavalli et al. (2011)	Increase the stability of the bone fragments
Koury and Ellis (1992), Fox and Kellman (2003)	Reduce the dead space susceptibility to infection
Yadavalli et al. (2011)	Avoid unnecessary trauma to the bone tissue
Koury and Ellis (1992), Ellis (2002), Chrcanovic (2012)	The possibility of postoperative infection due to preservation of intact teeth is relatively low
Literature encouraging extraction of the teeth on the fracture line during the surgery for fixation	
Irby (1979), Murthy and Lehman (2005), Thorén et al. (2008)	Preserved the teeth on the fracture line may develop pathologic conditions, like pulp necrosis and pericoronitis, later in life
Irby (1979)	If the teeth on the fracture line are exposed to the oral cavity, they are prone to further tissue damage and hematoma
Bradley (1965), Rowe and Killey (1968), Shetty and Freymiller (1989)	Teeth on the fracture line could be a cause of infection and potential obstacles for healing
Literature encouraging extraction of the teeth on the fracture line during the surgery for plate removal	
Rallis et al. (2006), Yamamoto et al. (2015)	Simultaneous plate and tooth extraction after surgical treatment of mandibular angle fractures may be beneficial to avoid related complications later in life

Verweij et al. 2016). Recent studies have reported that the incidence of bad splits during SSRO ranges from 0.2 to 14.6% (Verweij et al. 2014; Chrcanovic and Freire-Maia 2012). These bad split patterns can cause delayed bone healing, postoperative infection, and bone fragment isolation (Steenen and Becking 2016).

Existence of Mandibular Third Molars as a Risk of Bad Splits During Sagittal Split Ramus Osteotomy

Some studies have shown that impaction of the mandibular third molar may reduce bone mass at the surgical site, especially at the mandibular angle, and may increase the risk of bad splits (Steenen and Becking 2016; Mensink et al. 2013; Mehra et al. 2001). Therefore, it is recommended that the mandibular third molars should be extracted at least 6 months before surgery (Mensink et al. 2013; Verweij et al. 2016; Eshghpour et al. 2021). Steenent and Becking (2016) concluded that intraoperative extraction of the mandibular third molars minimizes postoperative complications. Eshghpour et al. (2021) reported that the presence of mandibular impacted mandibular third molars increased the incidence of bad splits 3.7-fold for SSRO. Besides, Mensink et al. (2013) found a significant correlation between intraoperative

extraction of mandibular third molars and the incidence of bad splits. Therefore, it is still controversial whether the presence/absence of mandibular third molars during SSRO increases the risk of intraoperative bad splits (Reyneke et al. 2002; Precious et al. 1998; Watzke and Heinrich 2002).

Conclusion

Fracture of the mandibular angle associated with the mandibular third molar can be a serious complication. Before surgery, it is necessary to evaluate the systemic risk factors and the condition of the third molars and the mandible in detail and to consider the surgical procedure and treatment plan. In addition, for patients in the risk group of fractures, we should explain the possibility of mandibular fractures during tooth extraction in advance. Intraoperatively, we need the use of appropriate surgical instruments and minimal bone removal and proper tooth division and should notice the sounds that suggest fractures. Besides, we should consider immediately performing radiography for cases with unexpected complications such as trismus, hypoesthesia of the lower lip, etc. appear during postoperative follow-up. Careful guidance and follow-up are also important, taking into the possibility of fractures, such as continuing to eat soft food for about 2–4 weeks after tooth extraction. The necessity and the timing of mandibular third molar extraction on the fracture line and with regard to mandibular osteotomy are still controversial.

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Alveolar Osteitis (Dry Socket) After Mandibular Third Molar Extraction

12

Kotaro Sato, Hisanobu Kamio, and Joe Iwanaga

Introduction

Alveolar osteitis (AO) is generally defined as the complete or partial absence of blood clot in the alveolar socket with pain at or near the tooth extraction site and with or without halitosis and is also described as a dry socket (DS). Generally, it manifests about 24 to 96 h after tooth extraction (Figs. 12.1 and 12.2). Crawford

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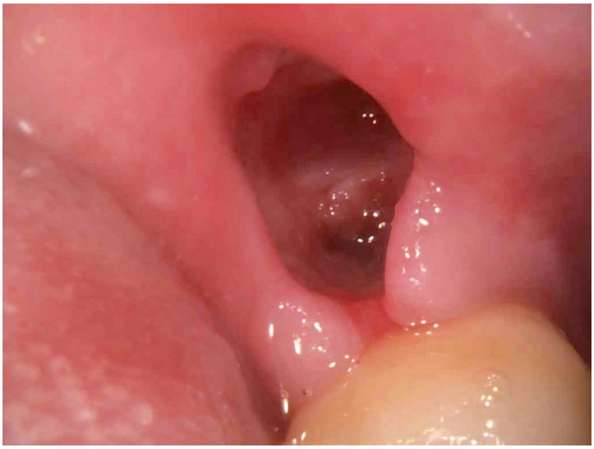


Fig. 12.1 Alveolar osteitis after extraction of the left mandibular third molar (Courtesy of Dr. Shiromoto)

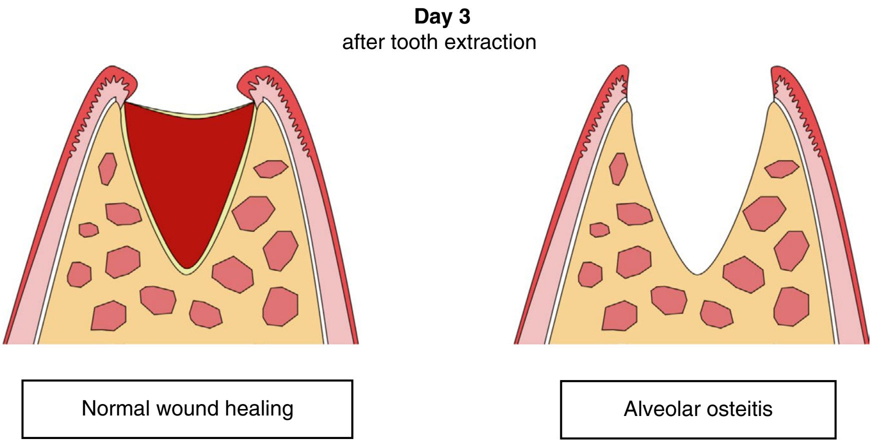


Fig. 12.2 Schematic drawing of normal wound healing and alveolar osteitis 3 days after extraction (Courtesy of Dr. Shiromoto)

(1896) originally named the condition a DS and stated, “There was no blood, no suppuration, no granulation, but a perfectly dry, clean socket”. This is the origin of the current definition.

Aetiology

AO is caused by the absence of blood clot or formation of it. Specifically, the formation of plasmin is a key factor. It has been reported that infection by bacteria or trauma, smoking, medication like oral contraceptive pills (OC), and so on link to the factor and could cause AO.

Incidence

Previous data, since 2005, has shown that the incidence of AO after tooth removal is in the general range from 1.4 to 6.1% (mean, 3.25%) (Akinbami and Godspower 2014; Abu Younis and Abu Hantash 2011; Halabi et al. 2012; Parthasarathi et al. 2011). If the third molar is focused on, the incidence ranges 1 to 23.5% (mean: 11.1%) (Almeida et al. 2016; Baqain et al. 2008; Cilasun et al. 2011; Chuang et al. 2008; Eshghpour and Nejat 2013; Eshghpour et al. 2013; Hatano et al. 2009; Leung and Cheung 2009; Malkawi et al. 2011; Renton et al. 2005). Thus, the incidence of AO after mandibular third molar removal seems higher than removal of the other teeth (Table 12.1). In order to avoid inferior alveolar nerve (IAN) damage, germectomy has been developed. Chiapasco et al. (1995) compared the incidence of AO between germectomy group (9 to 16 years old patients) and delayed removal of mandibular impacted third molars (patients over 24 years old). The incidence of AO in germectomy group and delayed removal group was 0% and 2.0%, respectively.

Table 12.1 Incidence of AO after mandibular third molar removal

	Year	Incidence (%)	Number		Teeth
Renton et al.	2005	9.8	10/102	extractions	Mandibular third molars
Baqain et al.	2008	9.5	14 of 148	Patients	Mandibular third molars
Chuang et al.	2008	7.4	296 of 4004	Patients	Maxillary and mandibular third molars
Leung et al.	2009	2.8	5 of 178	Extractions	Mandibular third molars
Hatano et al.	2009	8.5	10 of 118	Patients	Mandibular third molars
Cilasun et al.	2011	1	1 of 87	Extractions	Mandibular third molars
Parthasarathi et al.	2011	2.3	13 of 564	Extractions	Any teeth
Abu Younis et al.	2011	3.2	40 of 1305	Extractions	Any teeth
Malkawi et al.	2011	11.9	39 of 327	Patients	Mandibular third molars
Halabi et al.	2012	6.1	80 of 1302	Patients	Any teeth
Eshghpour et al.	2013	19.1	44 of 256	Extractions	Mandibular third molars
Eshghpour et al.	2013	23.5	68 of 290	Extractions	Mandibular third molars
Akinbami et al.	2014	1.4	19 of 1362	Extractions	Any teeth
Almeida et al.	2016	13.8	50 of 363	Patients	Mandibular third molars

Risk Factors

A number of risk factors have been reported, e.g. age, sex, menstrual cycle, oral hygiene, smoking history, local anaesthesia, previous surgical site infection, procedure site, surgical experience and difficulty of the extraction, and medication (Table 12.2).

In order to decrease the incidence of AO, we should check these risk factors for each patient before the procedure.

Age

Haraji and Rakhshan (2014) have included patients ranging in age from 17 to 31 years and found that aging has increased the odds of AO by around 1.9 times per year (Odds ratio: OR 2.86), and other studies have also reported the same tendency (Baqain et al. 2008; Chiapasco et al. 1995; Chuang et al. 2007); however, there are some studies reporting no relationship between age and AO (Abu Younis and Abu Hantash 2011; Eshghpour et al. 2013), and this still remains controversial.

Sex

Some studies have shown that the incidence of AO in females was higher than males (Oginni et al. 2003; Oginni 2008). Oginni (2008) and many researchers have suggested that oestrogen levels play a critical role in the incidence rate.

Menstrual Cycle

According to Eshghpour et al. (2013), the frequency of AO was significantly greater in the middle of the cycle than during the menstrual period in both the OC users and non-users ($p < 0.05$, OR 3.159). Due to oestrogen's potential risk to enhance

Table 12.2 Risk factors of AO development

	Risk factor
1.	Age
2.	Gender (female > male)
3.	Menstrual cycle
4.	Oral hygiene
5.	Smoking
6.	Local anaesthesia
7.	Previous surgical site infection
8.	Procedure site (posterior teeth)
9.	Surgical experience and difficulty of the extraction
10.	Medication

fibrinolytic activity, the higher frequency of developing AO in the middle of the cycle (between cycles) than during menstruation can be explained.

Oral Hygiene

Poor oral hygiene is one of the risk factors of AO (Oginni 2008; Peñarrocha et al. 2001). Regarding after impacted third molar extraction, Peñarrocha et al. (2001) have reported that poor oral hygiene patients who have high score of the oral hygiene index increased the incidence of AO by three times.

Smoking

Some studies have mentioned that smokers have a greater potential to develop AO compared to non-smokers. Halabi et al. (2012) have reported that smoking over five cigarettes within 24 h after extraction increased the OR (3.5). There are some hypotheses linking AO and smoking, and they also mentioned that smoking suppresses the formation of granulation tissue, an immune response, and inflammation. However, the exact mechanism has not been clarified yet.

Local Anaesthesia

Eshghpour and Nejat (2013) have reported that the number of cartridges of local anaesthesia including epinephrine could be the risk factor of AO, especially three cartridges compared to one or two cartridges. They have also speculated that the epinephrine delays the wound healing by reducing bleeding and oxygen tension and increases fibrinolysis (Noroozi and Philbert 2009); however the mechanism has not been clarified yet.

Previous Surgical Site Infection

Oginni (2008) has reported that a previously infected tooth, especially posterior tooth, is a high-risk factor of AO, and based on the logistic regression analysis in other studies, the odds ratio of the previous surgical site infection and periodontal disease was 3.3 and 7.5, respectively (Halabi et al. 2012; Parthasarathi et al. 2011).

Procedure Site

Some studies have reported that posterior teeth were one of the risk factors. According to Parthasarathi et al. (2011), the risk in posterior teeth was 5.2 times greater than the anterior teeth.

Surgical Experience and Difficulty of the Extraction

Larsen (1992) has reported that the practitioner's years of experience are a key factor of AO. Parthasarathi et al. (2011) analysed 564 extractions (not particularly mandibular third molar but any tooth) and concluded that the operator's experience (dental students versus qualified dentists or specialists) is a significant factor that affects incidence of AO (odds ratio, 5.5). Christensen et al. (2012) evaluated 313 mandibular third molars and resulted that a patient operated by a dental student had approximately 10 times higher risk of developing AO than an oral surgeon. Some papers mentioned that the surgical extraction itself is also a risk factor (Abu Younis and Abu Hantash 2011; Bortoluzzi et al. 2012; Halabi et al. 2012; Heng et al. 2007; Macgregor 1968; Oginni 2008). Abu Younis and Abu Hantash (2011) have reported that surgical extraction increased AO sevenfold compared to non-surgical extraction. Halabi et al. (2012) have reported that the odds ratio was 13.1. Surgical extraction could cause a delay in wound healing (Oginni 2008), and the reported studies above support this hypothesis.

Medication

1. Oral contraceptive pills (OC).

   Some researchers have reported that OC is one of the causes of AO. A meta-analysis of 16 studies by Xu et al. (2015) has shown that the incidence of AO was significantly greater in the OC group than in non-taking group (risk ratio,1.80), and Almeida et al. (2016) have reported that OC group had 4.3 times higher chance to develop DS than non-OC group (Table 12.3).
2. Antidepressant and antipsychotic.

   According to Parthasarathi et al. (2011), antidepressant and antipsychotic medications increases the risk of AO (odds ratio 5.9). They have considered the reason to be that these medications reduce the flow of saliva, and they might reduce some protective factors including saliva and potentially delay the wound healing process. Additionally, patients who take these drugs tend to show poorer oral hygiene, and thus they could raise the incidence of AO.

Table 12.3 Incidence of AO in the OC group and non-taking group

	AO	Non-AO	Total
OC group	**11**	18	29
Non-OC group	**16**	163	179
Total	27	181	208
Total incidence of AO in female: 13% (27 of 208)			
(AO in OC group) /(AO in non-OC group) = 37.9% (**11** of 29) /8.9% (**16** of 179) = 4.3			

AO alveolar osteitis, *OC* oral contraceptive
After Almeida et al. 2016

Prevention

The aforementioned risk factors need to be removed as many as we could before surgery. Besides that, some papers have suggested that chlorhexidine mouthwash, chlorhexidine gel, pre- and postoperative antibiotics usage, and consideration of surgical technique are effective for prevention of AO (Coulthard et al. 2014; Daly et al. 2012; Delilbasi et al. 2002; Eshghpour et al. 2014; Guazzo et al. 2018; Halabi et al. 2018; Lodi et al. 2012; Minguez-Serra et al. 2009). Regarding surgical technique, Coulthard et al. (2014) have found that triangular flap decreased the incidence of AO compared with envelope flap (risk reduction, 0.29) (Table 12.4 and Fig. 12.3).

Canellas et al. (2020) have reviewed 37 randomized controlled trials (6175 mandibular third molar surgeries in 4716 patients). They have found that intrasocket interventions which were plate-rich fibrin (OR, 0.28), chlorhexidine gel 0.2% (OR, 0.52), eugenol paste (OR, 0.06), recombinant bovine growth factor (OR, 0.07), colloidal silver gelatin sponge (OR, 0.05), and acellular dermal matrix (OR, 0.04) were significantly more effective than placebo. There is a possibility that chlorhexidine induces anaphylaxis reaction (Chiewchalermsri et al. 2020).

Table 12.4 Prevention method

1.	Chlorhexidine mouthwash
2.	Chlorhexidine gel
3.	Pre- and postoperative antibiotics usage
4.	Flap design (triangular flap)

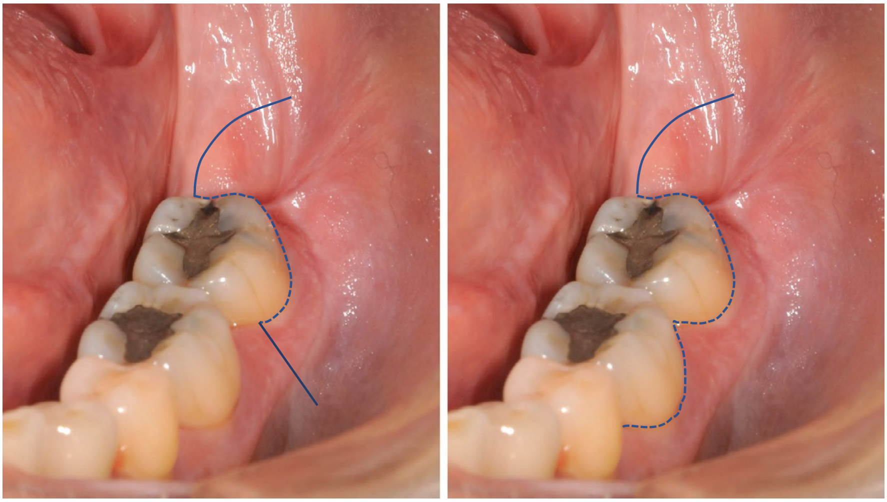


Fig. 12.3 Triangular flap versus envelope flap

Management

Conservative approach is recommended as an initial treatment of AO. Generally, irrigation with warm saline and obtundent dressing placement in the socket are common, practical, and effective methods. Kaya et al. (2011) and Xu et al. (2018) have reported that low-level laser therapy (LLLT) is an effective way to manage AO. If conservative treatment is not effective, we might consider invasive treatment, e.g. curettage to induce rebleeding. Generally speaking, AO heals within 2 weeks, so if the healing delays and postoperative pain continues, we must keep with other lesions in mind, such as second molar pulpitis, osteomyelitis, and neoplasia.

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Postoperative Infection and Antibiotics (Pre- and Post-administration)

13

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Introduction

Postoperative infection (PI) is a relatively common complication after the mandibular third molar extraction. It should be treated carefully as it can develop serious conditions.

Sukegawa et al. (2019) reported that in mandibular third molar extractions with prophylactic antimicrobial therapy, there were no PI in 812 maxillary cases, while the rate was 1.94% (31/1595) in mandibular cases. Although the risk of infection seems to be high for the extraction of mandibular third molars compared to maxillary molars, the frequency of PI associated with tooth extraction, in general, is not

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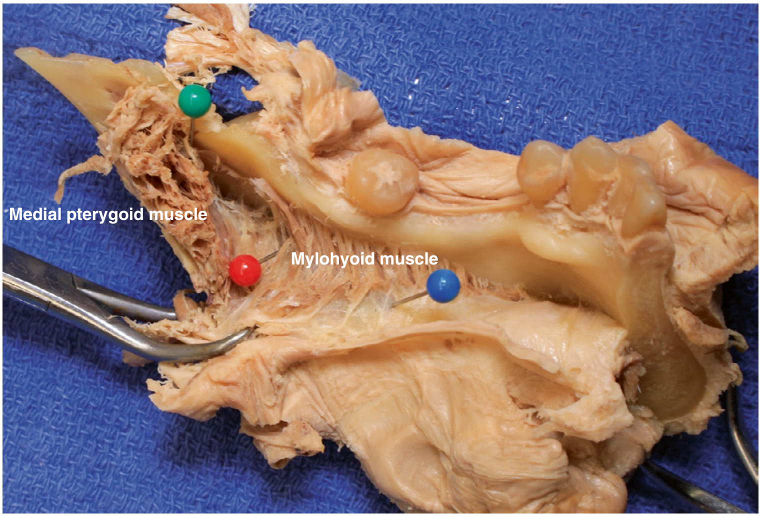


Fig. 13.1 The sublingual (blue), submandibular (red), and pterygomandibular (green) spaces are shown

considered high. However, it should be noted that PI of mandibular third molar can spread rapidly to the submandibular space, masticatory muscles, and even the parapharyngeal spaces. Alise et al. stated that dental infections are one of the most frequent aetiologies of deep neck infection and if the infection extends to the parapharyngeal space or into the mediastinum, it may cause sepsis and respiratory distress, leading to death in severe cases. Anatomically, the roots of the mandibular teeth lie next to the sublingual/submandibular space (Fig. 13.1), which allows dental infections to spread to these regions. Thus, proper infection control is necessary for safe mandibular third molar extraction. In this chapter, the concept, prevention, and treatment of PI, including the usage of antibiotics, based on the latest research findings will be discussed.

The Risk Factors of Surgical Site Infections

Perioperative infections, especially surgical site infections (SSIs), are one of the most serious and preventable complications in surgery. According to the Centers for Disease Control and Prevention guidelines for prevention of surgical site infection (The CDC guidelines), SSIs are defined as infections at the site of a surgical operation. The guidelines suggest that half of all SSIs can be prevented by using evidence-based strategies.

The CDC guidelines list the risk of SSIs for patient and operation factors (Table 13.1). In the case of mandibular third molar extraction, the main patient risk factors may include age, nutritional status, diabetes, smoking, obesity, and colonization with microorganisms. On the other hand, the main operation factors may

Table 13.1 The risk of surgical site infection (After Mangram et al. 1999)

Patient factor	Operation factor
Age	Duration of surgical scrub
Nutritional status	Skin antisepsis
Diabetes	Preoperative shaving
Smoking	Preoperative skin prep
Obesity	**Duration of operation**
Coexistent infections at a remote body site	**Antimicrobial prophylaxis**
Colonization with microorganisms	**Operating room ventilation**
Altered immune response	**Inadequate sterilization of instruments**
Length of preoperative stay	**Foreign material in the surgical site**
	Surgical drains
	Surgical technique

Bold: Factors strongly associated with to extraction of mandibular wisdom tooth

include duration of operation, antimicrobial prophylaxis, operating room ventilation, inadequate sterilization of instruments, foreign material in the surgical site, and surgical technique such as poor haemostasis or failure to obliterate dead space. Antibiotics, one important factor, will be focused on here.

Classification of SSIs and Prophylactic Preoperative Administration of Antibiotics

According to the CDC guidelines, there are four categories of SSIs (Table 13.2):

Class I: Clean.
Class II: Clean-contaminated.
Class III: Contaminated.
Class IV: Dirty-infected.

Extraction of a mandibular third molar is classified as Class II. The guidelines mention that prophylactic preoperative administration of antibiotics should be used only when necessary. Although no further refinement of timing can be made for preoperative antibiotics based on clinical results, preoperative antibiotics should be administered so that blood levels are sufficient at the start of surgery and maintain therapeutic levels of the antibiotics in both serum and tissues throughout the operation and a few hours after suturing. In addition, the guidelines mention that additional prophylactic antibiotics after operation should not be administered in Class I and Class II procedures. However, there are some surgeries that fall into these classes that require antimicrobial prophylaxis after the surgery. This includes all cardiac operations, vascular operations regardless of site, and most neurosurgical procedures.

Therefore, a single dose of antibiotics administered about 1 h before the extraction of third molar for healthy adults is generally considered to be sufficient for infection control, and ideally, we should not administer additional prophylactic

Table 13.2 Surgical wound classification (after Mangram et al. 1999)

Class I (Clean)	An uninfected operative wound in which no inflammation is encountered and the respiratory, alimentary, genital, or uninfectedurinary tract is not entered. In addition, clean wounds are primarily closed and, if necessary, drained with closed drainage. Operativeincisional wounds that follow nonpenetrating (blunt) trauma should be included in this category if they meet the criteria
Class II (clean-contaminated)	**An operative wound in which the respiratory, alimentary, genital, or urinary tracts are entered under controlled conditions and without unusual contamination. Specifically, operations involving the biliary tract, appendix, vagina, and oropharynx are included in this category, provided no evidence of infection or major break in technique is encountered**
Class III (contaminated)	Open, fresh, accidental wounds. In addition, operations with major breaks in sterile technique (e.g. open cardiac massage) or gross spillage from the gastrointestinal tract and incisions in which acute, nonpurulent inflammation is encountered are included in this category
Class IV (dirty-infected)	Old traumatic wounds with retained devitalized tissue and those that involve existing clinical infection or perforated viscera. This definition suggests that the organisms causing postoperative infection were present in the operative field before the operation

Bold: Extraction of mandibular third molar is categorized in Class II

antibiotics after tooth extraction. According to the Sanford Guide to Antimicrobial Therapy (the Sanford Guide) (Gilbert et al. 2021), a single intravenous dose of cefazolin or clindamycin is recommended for head and neck surgery. In extraction of mandibular third molar, a single oral dose of amoxicillin and amoxicillin/clavulanic acid is also known to be effective (Lacasa et al. 2007; Lopez-Cedrun et al. 2011). Of course, it is true that there are various opinions about the administration of antibiotics after tooth extraction, which will be discussed in detail later. In summary, the following points should be taken into consideration when extracting mandibular third molars. We should check patient factors preoperatively, and if necessary, patient information should be shared with the regular physician to confirm the general condition of the patient. In addition, we should extract teeth with attention to operation factors, ideally with pre-administration of prophylactic antibiotics.

Oral Bacteria Causing Postoperative Infection

According to the CDC guidelines, it is necessary to use antibiotics with an in vitro spectrum that covers possible probable intraoperative contaminants for the operation. The oral cavity is colonized by a larger variety of bacterial flora compared to other anatomical areas. More than 700 species of bacteria have already been identified. The oral microbiome is incredibly complex (Krishnan et al. 2017). Generally considering, PI in the oral cavity are mixed infections caused by these bacteria of oral anaerobic-aerobic flora (Table 13.3). Investigating bacteraemia caused by

Table 13.3 Typical bacteria causing postoperative infection in oral area

Anaerobes	*Peptostreptococcus* species
	Eubacterium species
	Actinomyces species
	Fusobacterium species
	Prevotella species
	Veillonella species
Aerobes	*Streptococcus* species
	Neisseria species

surgical extraction of half impacted mandibular third molar in 16 young adults, blood cultures contained 31 species (74% anaerobes), with about 4 species isolated per subject (Rajasuo et al. 2004). Concretely anaerobic bacteria *Prevotella*, *Eubacterium*, and *Peptostreptococcus species* are often detected, and among aerobic bacteria, *Streptococcus* and *Neisseria species* are typical ones. It is reported that these species found in the blood were also isolated from the periodontal pockets (93%) and from the extraction sockets (43%), and the frequency of bacteraemia due to tooth extraction may be higher than expected. Therefore, we need to choose antibiotics that are usually broad-spectrum molecules against these oral bacteria in order to prevent PI in the oral region (Martins et al. 2017).

Prophylactic Postoperative Administration of Antibiotics

Although routine postoperative antibiotic prophylaxis is not recommended for mandibular third molar extractions, as described in the CDC guidelines, there are a few reports that support the use of antimicrobials after mandibular third molar extractions. Lacasa et al. (2007) showed that 5-day therapy with amoxicillin/clavulanate twice a day after extraction of a mandibular impacted third molar was effective in reducing local infection. In particular, they showed that the risk of PI with placebo, preoperative single-dose prophylaxis, and postoperative therapy was 24%, 9%, and 4%, respectively, in the extraction of mandibular third molars with bone removal and noted a significant effect of not only preoperative single-dose prophylaxis but also postoperative antimicrobials. Recent studies have also shown that there was a statistically significant decrease in postoperative inflammatory after mandibular impacted third molar removal complications of 40% in the isolated postoperative antibiotics group compared with no antibiotic use (Morrow et al. 2017).

It is probably true that antibiotics are still widely used postoperatively to prevent PI after extraction of mandibular impacted third molar. In a survey conducted by Arteagoitia et al. (2016), 83% of the dentists reported the need to prescribe antibiotics for the extraction of mandibular impacted third molar; however, only 4.6% of the dentists reported the need to prescribe antimicrobials only preoperatively. Furthermore, another study reported most patients believe that antibiotics are necessary after routine dental extraction to prevent PI. Therefore, the dentist might need

to explain to the patient that most of the current scientific literature, including the CDC guidelines, do not support the routine usage of antibiotics after tooth extraction.

The Clinical Practice Guidelines for Antimicrobial Prophylaxis in Surgery states that administration of antibiotics should be limited a single dose within 24 h after surgery to prevent resistant bacteria (Bratzler et al. 2013). A recent study found that there was no significant difference in PI rates between 24 h dose group after extraction and 48 h dose group; the PI rate did not change significantly over time (Yoshida et al. 2021a, b). It shows the total incidence of PI of mandibular third molar extraction with amoxicillin was 1.2% (4/340 cases), 24 h dose group is 0.9% (1/106 cases), and after 48 h dose group was 1.3% (3/234 cases). Stephan et al. mentioned that even after cardiac surgery, which is far more invasive than tooth extraction, administration of antibiotics should only be limited to 48 h.

Based on these reports, if postoperative administration of antibiotics after mandibular third molar extraction is considered, it should be sufficient for up to 24 h or, at most, 48 h after surgery.

Typical Antibiotics Used for Postoperative Infection After Tooth Extraction

In order to prevent antibiotic resistance that is a major international challenge, proper usage of antibiotics is needed in the dental field as well as in other medical fields. For the treatment of PI in the oral cavity, amoxicillin and amoxicillin/clavulanic acid, which have higher bioavailability, are now recommended (Lacasa et al. 2007; Lopez-Cedrun et al. 2011), although, in the past, third-generation cephalosporins were often used. The same is true for prophylactic administration. Yoshida et al. (2021a, b) reported that although they selected postoperative administration of penicillin (amoxicillin) instead of a third-generation cephalosporin from 2015 to 2019, there was no significant difference in the incidence of PI after mandibular third molar extraction.

The major antibiotics for the treatment (sometimes prophylactic administration) of PI after tooth extraction currently recommended by the Sanford Guide are summarized in Table 13.4. The first choice is penicillin. We need to be careful in their usage for patients with renal disease such as the elderly or dialysis patients because amoxicillin and amoxicillin/clavulanic acid are metabolized by the kidneys. These patients with a creatinine clearance <50 ml/min may need to extend the antibiotic administration interval or reduce the dosage.

Table 13.4 Major antibiotics recommended by the Sanford Guide

	Antibiotics
First choice	Penicillin (amoxicillin, amoxicillin/clavulanic acid)
For patients with an allergy to penicillin	Lincomycin (clindamycin)
	Macrolide (clarithromycin, azithromycin)
For considering β-lactamase-producing anaerobes	Carbapenem (meropenem)
	Antibiotic preparations containing β-lactamase inhibitor (sulbactam sodium ampicillin sodium)

For patients with an allergy to penicillin, lincomycins are often chosen as the second-line drug. Because lincomycins such as clindamycin have gastrointestinal side effects, it should be used carefully in patients with a history of enteritis.

In some cases, it may be necessary to choose macrolides such as clarithromycin and azithromycin instead of penicillin or lincomycin because macrolides are metabolized by the liver. Macrolide antibiotics should be administered with care to patients such as those who are taking immunosuppressive drugs like calcineurin inhibitor with autoimmune diseases or after organ transplantation. Some macrolides inhibit cytochrome P450(CYP)3A4, a drug-metabolizing enzyme in the liver, resulting in higher blood levels of immunosuppressive drugs(Westphal 2000).

Diagnosis and Treatment of Severe Postoperative Infection

Unfortunately, there are some cases where PI cannot be controlled and develops into a deep neck infection. Alise et al. reported that 70.6% of deep neck infections were dental infections. In fact, in their review of 263 deep neck infection cases, they reported that one patient (0.4%) died and 30 patients (11.4%) had complications. They also suggested that the prognosis can be excellent in both medically and surgically managed groups if started and designed early and promptly. Additionally, odontogenic infections are the most common cause of descending mediastinitis and accounted for 60% of the cases (Sancho et al. 1999). Since descending mediastinitis is serious with a mortality rate of around 50% (Cirino et al. 2006), the initial treatment of odontogenic infections is particularly important.

Pablo et al. mentioned that the successful management of deep neck infection depends on a prompt diagnosis and appropriate treatment, including the elimination of causative factors. They recommended the detailed examination to identify the cause of infection with panoramic radiographs and computed tomography (CT) imaging. In particular, contrast-enhanced CT imaging can be useful for evaluating the location of the abscess space, although caution is needed to avoid allergic reactions to iodine-based contrast media.

In addition, it is also important to identify the causative organism and test for antibiotic sensitivity by bacteriological examination after puncture aspirate from an abscess or blood culture (Boyanova et al. 2006). In severe cases of PI, it is necessary to consider the possibility that parasitic anaerobes or β-lactamase-producing bacteria may be the cause. For example, the β-lactamases of *Prevotella* degrade penicillins and cephem antibiotics, including third-generation antibiotics, so that antibiotics with potent and broad-spectrum antibacterial activity against the causative organisms, including β-lactamase-producing anaerobes, must be changed. According to the Sanford Guide, administration of carbapenems or β-lactamase inhibitors is recommended for severe oral infections. Although meropenem or sulbactam sodium ampicillin sodium is known as representative antibiotic, it is recommended to collaborate with the infection control team when using these antibiotics. This is because that these antibiotics may alter the bacterial flora of the hospital and patients, which may lead to colonization or resistance.

If there is a risk of respiratory distress due to swelling around the neck, under the jaw, on the face or laryngeal oedema, hospitalization for treatment should be considered. Boscolo-Rizzo et al. (2012) revealed that 93.2% of patients with deep neck infections complained of neck swelling and 56.2% of patients complained of difficulty or pain during swallowing. In the case of emergency, respiratory management including tracheostomy should be considered. And depending on the patient's history, treatment should be performed in collaboration with other departments. It is also a good idea to examine the patient in detail to check for any hidden risk factor diseases such as untreated diabetes.

In order to prevent PI caused by a mandibular third molar extraction, it is recommended that a single dose of antibiotics be administered approximately 1 h prior to surgery. On the other hand, it should be noted that the efficacy of prophylactic administration of antimicrobials after tooth extraction is debatable. If postoperative antimicrobial prophylaxis for tooth extraction is necessary, it should be limited to 24 h postoperatively or at most 48 h. It will be necessary to continue to actively collect information on the impact of SSI risk factors and to prevent or treat appropriately. By taking sufficient preventive care against infection, mandibular third molars can be safely extracted.

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14 Postoperative Pain and Drugs

Kyoichi Obata, Daniel Shen, Quang Do, and Joe Iwanaga

Introduction

After third molar extractions, one of the most reported complications is postoperative pain. Various antipyretic analgesics are used to reduce an inflammation and to relieve a pain after the extraction. One of the most prescribed regimens is a combination of acetaminophen and hydrocodone, such as Vicodin. Another popular regimen is acetaminophen combined with non-steroidal anti-inflammatory drugs (NSAIDs). In addition to these regimens, some providers also prescribe postoperative corticosteroids to reduce postoperative inflammation and pain. Other than the NSAIDs, various antipyretic analgesics are used, including acetaminophen (paracetamol), a non-pyrine analgesic, and an opioid analgesic such as tramadol. It is important to understand the properties of these drugs and chose appropriate one (Table 14.1) (Baker and Perazella 2020; Becker 2010). This chapter will briefly go over the mechanisms of action of these popular postoperative regimens and the reasonings for each regimen to manage postoperative pain after third molar extractions.

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Table 14.1 Characteristics of various antipyretic-analgesic

Antipyretic analgesics	$t_{1/2}$	Total dose/day (dosing)
NSAIDs		
Carboxylic acids		
Acetylsalicylic acid	0.25	1200–4000 mg (2–4×/day)
Acetic acids		
Diclofenac	1–2	100–150 mg (2–3×/day)
Etodolac	6.4	400–1200 mg (2–4×/day)
Ketorolac	5–6	40 mg (4×/day)
Indomethacin	5–10	75–150 mg (2–4×/day)
Propionic acids		
Loxoprofen	1.2–1.3	60–180 mg (2–3×/day)
Flurbiprofen	5–7	200–300 mg (2–3×/day)
Ibuprofen	1.8–2	800–3200 mg (4×/day)
Naproxen	12–17	500–1000 mg (2×/day)
Oxaprozin	38–44	1200 mg (1×/day)
Enolic acids		
Piroxicam	45–50	10–20 mg (1×/day)
Meloxicam	15–22	15 mg (1×/day)
Lornoxicam	1.7–4.1	12–24 mg (3×/day)
Fenamates		
Mefenamic acid	2	1000 mg (4×/day)
Meclofenamate	1–5	150–400 mg (3–4×/day)
Selective COX-2 inhibitors		
Celecoxib	11	100–400 mg (1–2×/day)
Non-pyrin		
Acetaminophen (paracetamol)	2.5–3.5	200–1000 mg (3–4×/day)
Opioid		
Tramadol	7.6–8.6	50–100 (4×/day)

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NSAIDs

Most of the NSAIDs inhibit the activity of cyclooxygenase enzymes (COX), which are enzymes that catalyse the formation of prostaglandins from arachidonic acid. The decrease of prostaglandins, which induce a pain and inflammation, thereby reducing inflammation and relieving a pain. The COX are classified into two types of isozymes: COX-1 that is essential to the control of the physiological functions and COX-2 that is induced by inflammatory stimulus. Most of the NSAIDs inhibit both COX-1 and COX-2, causing side effects such as digestive tract disorder and renal disfunction (Baker and Perazella 2020; Sugano et al. 2012; Lewis et al. 2002). To reduce the side effects, selective COX-2 inhibitors have been developed (Walker 2018). Overall, oral NSAIDs have been found to be safe and effective for mild to moderate postoperative pain for most patients. However, NSAIDs should be avoided in patients with history of kidney disease due to their effects on kidney blood flow. Furthermore, NSAIDs should be avoided in pregnant patients due to risk of premature closure of foetal ductus arteriosus and damage to the foetal kidneys. NSAIDs should also be avoided in those with haemorrhagic disorder or anticoagulants due to risks of GI bleeding. The characteristics of various NSAIDs will be described below. Note that the results of comparative studies of drugs may differ depending on doses and usage.

Carboxylic Acids

Aspirin is the synthetic drug produced by acetylizing sodium salicylate, an antipyretic analgesic. The analgetic effect of aspirin is equivalent to that of acetaminophen. Since aspirin often induces digestive tract disorder, commercially available aspirins generally contain antacid (Edwards et al. 1999).

Acetic Acids

Diclofenac is a powerful NSAID whose analgetic effect on a pain after the extraction of a tooth is superior to loxoprofen (Nourwali et al. 2020), ibuprofen, acetaminophen (Gazal and Al-Samadani 2017), and naproxen and almost equivalent to tenoxicam, flurbiprofen, and tramadol.

Etodolac is an NSAID that was showed to preferentially inhibit COX-2 in post-marketing studies. The analgetic effect of etodolac is almost equal to that of diclofenac and superior to that of ibuprofen.

Propionic Acids

Propionic acids generally have an analgetic effect, anti-inflammatory effect, and antipyretic effect as well as a white blood cell inhibitive effect. Loxoprofen is one

of the most prescribed NSAIDs in several countries for a pain after the extraction of a tooth. The analgetic effect of loxoprofen is slightly lower than that of diclofenac, while loxoprofen is less likely to cause digestive tract disorder because of its prodrug properties (Nourwali et al. 2020). Flurbiprofen is one of the NSAIDs that can be administered intravenously. There have been no studies comparing flurbiprofen with other drugs in terms of an analgetic effect on a pain after the extraction of a tooth. However, reports from other regions indicate that the analgetic effect of flurbiprofen is superior to that of tramadol (Wang et al. 2020), diclofenac, and ketorolac (Alreshidi et al. 2015). Ibuprofen is an anti-inflammatory drug that appears on the list of the WHO Model Lists of Essential Medicines and widely used around the world. Ibuprofen has an intermediate analgetic effect, and the effect is superior to that of acetaminophen (Bailey et al. 2013; Mehlisch et al. 2010) and inferior to that of diclofenac (Gazal and Al-Samadani 2017). Ibuprofen is one of the few NSAIDs that can be safely used for children (Radman et al. 2019; Kanabar 2017).

Enolic Acids (Oxicam)

Meloxicam and lornoxicam are characterized by a very strong analgetic effect and a prompt effect. The analgetic effect of meloxicam and lornoxicam is significantly higher than that of flurbiprofen (Isola et al. 2019) and diclofenac (Orozco-Solís et al. 2016).

Selective COX-2 Inhibitors

To reduce the side effects caused by COX1, various selective COX-2 inhibitors were developed. However, many selective COX-2 inhibitors were withdrawn from the market after investigations revealed that they induced cardiovascular disorders.

Presently, celecoxib is mainly used as a selective COX-2 inhibitor (Shin 2018). The analgetic effect of celecoxib is superior to that of ibuprofen (Isola et al. 2019) and comparable to that of loxoprofen (Yamashita et al. 2014).

Some side effects that should be kept in mind when using the NSAIDs will be listed in the paragraphs described below. The studies on the NSAIDs show that the analgesic and antipyretic effects of the NSAIDs do not change when they are administered more than the upper limits of the doses. On the contrary, the risk of side effects increases (Fig. 14.1) (Nagi et al. 2015; Becker 2010). If an administered NSAID does not produce a sufficient effect, a change of the drug or an addition of any other drug having a synergistic effect is recommended.

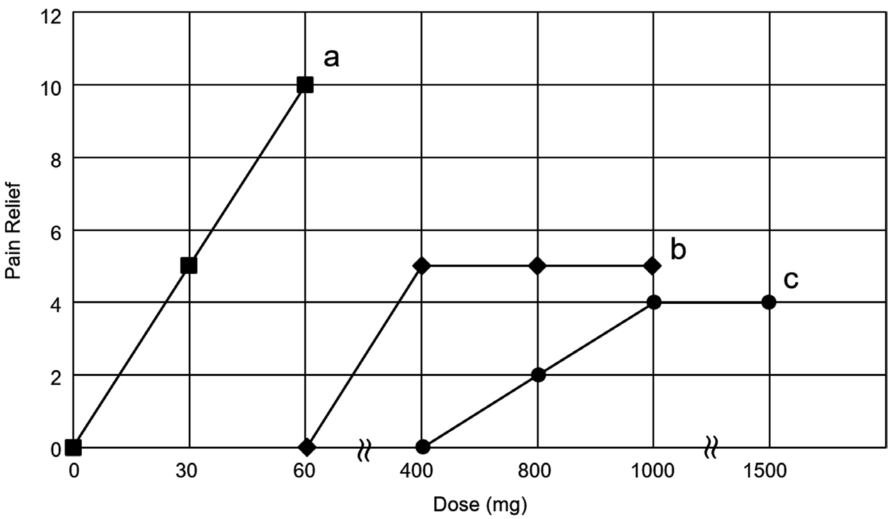


Fig. 14.1 Dose-response curves of typical oral analgesics. For non-opioid analgesics such as ibuprofen and acetaminophen (or paracetamol), their analgetic effects are not enhanced after the doses exceed certain amounts. (This phenomenon is called "ceiling effect.") In an opioid analgesic such as morphine, the analgetic effect is enhanced proportionally as the dose increases (based on Baker and Perazella 2020). (**a**, morphine; **b**, ibuprofen; **c**, acetaminophen)

Digestive Tract Disorder

Among the side effects of the NSAIDs, digestive tract disorder occurs most frequently (Wallace et al. 2011). When a NSAID inhibits COX-1, a gastric mucosa is damaged and a gastric ulcer is formed. The studies on the NSAIDs showed that approximately 30% of patients with the ulcers caused by the NSAIDs developed an ulcer in a short time (1–10 days) from the start of the administration (Nakashima et al. 2005; Lewis et al. 2002).

Among the NSAIDs, celecoxib and etodolac have a high affinity for COX-2, and some prodrugs that do not inhibit COX when they pass through a digestive tract (such as loxoprofen and indomethacin farnesil) are less likely to cause digestive tract disorder (Fig. 14.2) (Varrassi et al. 2020; Halen et al. 2009; Antman et al. 2005). As a preventive measure against the digestive tract disorder, a combined use of a NSAID and a proton pump inhibitor (PPI) is recommended (Yang et al. 2017; Sugano et al. 2012). It has been also reported that use of a selective COX-2 inhibitor alone or a combination of PPIs reduced the occurrence of the upper digestive tract disorder in comparison with a combined use of a NSAID and a PPI (Yuan et al. 2016). It is advisable to choose an appropriate drug in consideration of the morbid state of a patient and a dosing period.

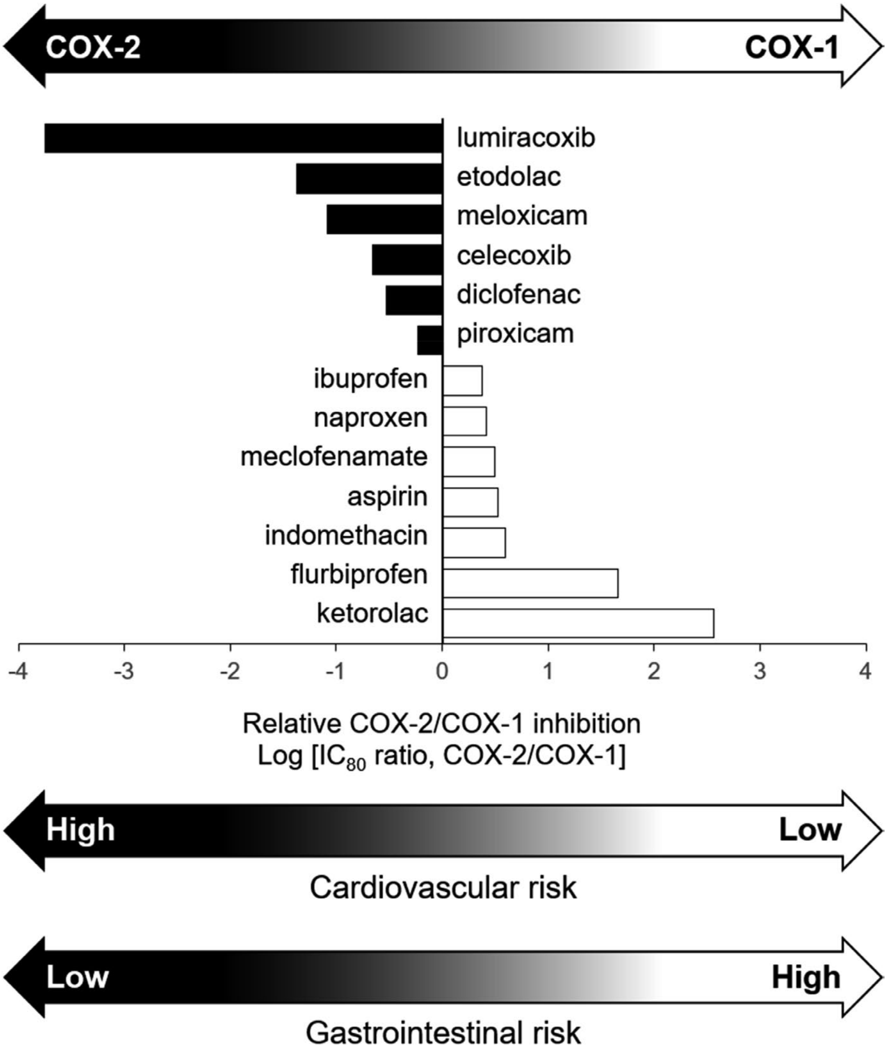


Fig. 14.2 COX-1/COX-2 selectivity of various NSAIDs. The NSAIDs are classified into two groups by their selectivity: ones that exhibit a high selectivity on COX-1 and the rest that exhibits high selectivity on COX-2. The selective COX-1 inhibitors have the low risk of cardiovascular diseases, but the risk of gastrointestinal diseases is high, whereas the selective COX-2 inhibitors are the opposite of the selective COX-1 inhibitors (Based on Varrassi et al. 2020; Antman et al. 2005)

Renal Disfunction

When the production of prostaglandin is curbed by the inhibition of COX in the kidney, renal blood flow decreases by the renovascular contraction, the reabsorption of sodium increases, and urinary volume decreases by the action of vasopressin, and acute kidney injury (AKI) develops (Baker and Perazella 2020). The kidney disease clinical guidelines recommend that the long-term use of a NSAID be avoided for patients with a chronic kidney disease (CKD) if GFR > 30 ml/min/1.73 m^2. If GFR < 30 ml/min/1.73m^2, a NSAID must not be used (Inker et al. 2014). COX-2 is a constitutive enzyme in the kidney, so the administration of selective COX-2 inhibitors should be considered as well as the NSAIDs for patients with CKD. A large-scale cohort study comparing the selective COX-2 inhibitors with the general NSAIDs in terms of a risk of AKI in elderly patients showed that there was not a significant difference between them (Gooch et al. 2007). Moreover, the risk of AKI with celecoxib was dose-dependent (Shin 2018).

Bronchial Asthma

An asthmatic attack is induced when a NSAID inhibits COX-1, which dilates a bronchus (Tan and Hsu 2016). Particularly, for patients with a history of asthma, approximately 7% of them is presumed to recur asthma. Therefore, the administration of the NSAIDs to the population is contraindicated (Rajan et al. 2015).

Cardiovascular Disorder

After the studies on selective COX-2 inhibitors that the inhibitors increase cardiovascular events, it was also found that standard NSAIDs increased the risk of cardiovascular events (Table 14.2) (Kang et al. 2020; Varga et al. 2017). For a patient who suffered a cardiovascular event, the use of NSAIDs should be avoided.

Table 14.2 The risk of cardiovascular events with standard NSAIDs and selective COX-2 inhibitors

	Myocardial infarction (RR)	Stroke (RR)	Cardiovascular death (RR)
Standard NSAIDs			
Diclofenac	0.82 (0.29–2.20)	2.86 (1.09–8.36)	3.98 (1.48–12.70)
Ibuprofen	1.61 (0.50–5.77)	3.36 (1.00–11.60)	2.39 (0.69–8.64)
Naproxen	0.82 (0.37–1.67)	1.76 (0.91–3.33)	0.98 (0.41–2.37)
Selective COX-2 inhibitors			
Celecoxib	1.35 (0.71–2.72)	1.12 (0.60–2.06)	2.07 (0.98–4.55)
Rofecoxib	2.12 (1.26–3.56)	1.07 (0.60–1.82)	1.58 (0.88–2.84)
Lumiracoxib	2.00 (0.71–6.21)	2.81 (1.05–7.48)	1.89 (0.64–7.09)

Other Analgesics

Acetaminophen (Paracetamol, APAP)

Acetaminophen does not inhibit COX, and therefore it does not reduce the inflammation of a peripheral nerve (Anderson 2008). Acetaminophen is an analgesic that inhibits cyclooxygenase enzymes, though it primarily targets the central nervous system instead of the peripheral tissues due to its ability to cross the blood-brain barrier and is considered to act on a thermoregulatory centre and decreases a body temperature by dilating cutaneous blood vessels and also increases the threshold of a pain that is recognized with a thalamus and a cerebral cortex, thereby relieving a pain (Ghanem et al. 2016; Mehlisch et al. 2010). Acetaminophen is less likely to cause a digestive tract disorder and a renal disfunction and has a low risk of bronchial asthma (McCrae et al. 2018). However, if a high dose of acetaminophen is administered for a long term, drug-induced hepatopathy can occur (Atkinson et al. 2015). For patients who drink a large quantity of alcoholic beverages habitually, they are especially more likely to develop hepatopathy (Zimmerman and Maddrey 1995). Compared with the general NSAIDs such as ibuprofen and diclofenac, the analgetic effect of acetaminophen is considered to be much lower. However, the analgetic effect can be enhanced by reviewing the administration interval and the dose and using it together with a NSAID or opioid analgesic (Bailey et al. 2013; Mehlisch et al. 2010; Fricke et al. 2004). Acetaminophen may also have additional analgesic effects due to involvement of its metabolites in the opioidergic pathway, cannabinoid systems, and serotonergic pathway. Acetaminophen can be found as an over-the-counter drug in unit doses of 325 mg or 500 mg under the brand name of Tylenol. Prescription-strength acetaminophen can be prescribed in unit dose of 650 mg or 1000 mg. While APAP has been found to be relatively safe and effective, there are risks of overdosing and hepatotoxicity. The maximum therapeutic dose of acetaminophen is 4 g/day for adult and 50–75 mg/kg/day in children.

Opioids

Opioids are a class of analgesics that act on the agonist of opioid receptors, often in the central nervous system. The most clinically relevance receptors activated for analgesia are mu and kappa receptors. The mu receptor does not have ceiling effect, so opioids have greater efficacy at higher doses. Unfortunately, activation of the mu opioid receptor can cause respiratory depression and dependence. The activation of kappa opioid receptor can also cause respiratory depression. Due to their risks of addiction and overdose, prescriptions are required for most opioids.

Opioids are substances that act on opioid receptors to produce effects similar to those of endogenous opioid peptides including endorphins, enkephalins, and dynorphins (Hersh et al. 2020). Opioids are effective for the treatment of moderate to severe postoperative and cancer-related pain, prescribed according to the degree of

Table 14.3 List of opioids and conversion factors for opioids. The conversion factor indicates how many mg of that opioids is equivalent to 1 mg of morphine (morphine milligram equivalent, MME). The Centers for Disease Control and Prevention recommends no more than 50 MME per day, and when increasing the dose above 50 MME, the benefits and harms should be evaluated, and increases to 90 MME or more should be avoided

Opioid (doses in mg/day)	Conversion factor	Potency of opioids
Codeine	0.15	Weak
Tramadol	0.2	Weak
Tapentadol	0.4	Strong
Morphine	1	Strong
Hydrocodone	1	Weak
Oxycodone	1.5	Strong
Fentanyl transdermal (in mcg/hr)	2.4	Strong
Oxymorphone	3	Strong
Hydromorphone	4	Strong
Methadone	4–12	Strong

pain using a conversion chart with morphine as 1 (Table 14.3) (Centers for Disease Control and Prevention (CDC) 2021). Dentists in the United States prescribed a range of opioids containing hydrocodone, codeine, oxycodone, and tramadol, those in the Brazil prescribed codeine and tramadol, and those in the English prescribed dihydrocodeine (Lino et al. 2019; Organisation for Economic Co-operation and Development (OECD) 2021).

However, there are few situations that force the use of opioids in dentistry. The survey on postoperative pain for dental surgery showed that no statistically significant difference in overall satisfaction with pain management was found between opioid users and nonusers (Nalliah et al. 2020). Furthermore, the survey on postoperative pain for undergoing the surgical removal of impacted mandibular third molar requiring bone removal showed that the addition of codeine to a regimen of paracetamol and ibuprofen does not improve analgesia (Best et al. 2017). Dental pain occurs with tooth extraction, caries, and periodontal disease progression. These are most related to tissue injury and inflammation, and anti-inflammatory analgesics such as NSAIDs should be used. Opioids act on the central nervous system to suppress pain, but do not treat the tissue injury and inflammation (Fig. 14.3) (Steinmetz et al. 2017; Mesbah et al. 2016). Opioids can have a variety of side effects, even when taken as directed such as constipation, nausea, dry mouth, and sleepiness. There are also opioid-specific adverse events such as tolerance, dependence, and overdose. NSAIDs also have a variety of side effects, but they rarely lead to tolerance, dependence, or overdose as opioids do (Table 14.4) (Centers for Disease Control and Prevention (CDC 2021; Nafziger and Barkin 2018).

On the other hand, opioid prescriptions after dental treatment have a variety of social problems. First, prescription rates for opioids differed by socioeconomic status and race and ethnicity. Low income, less education, non-Whites, older, and having Medicaid insurance (medical care services for people with low income in the United States) had higher percentages of opioid prescriptions (Miller et al. 2020;

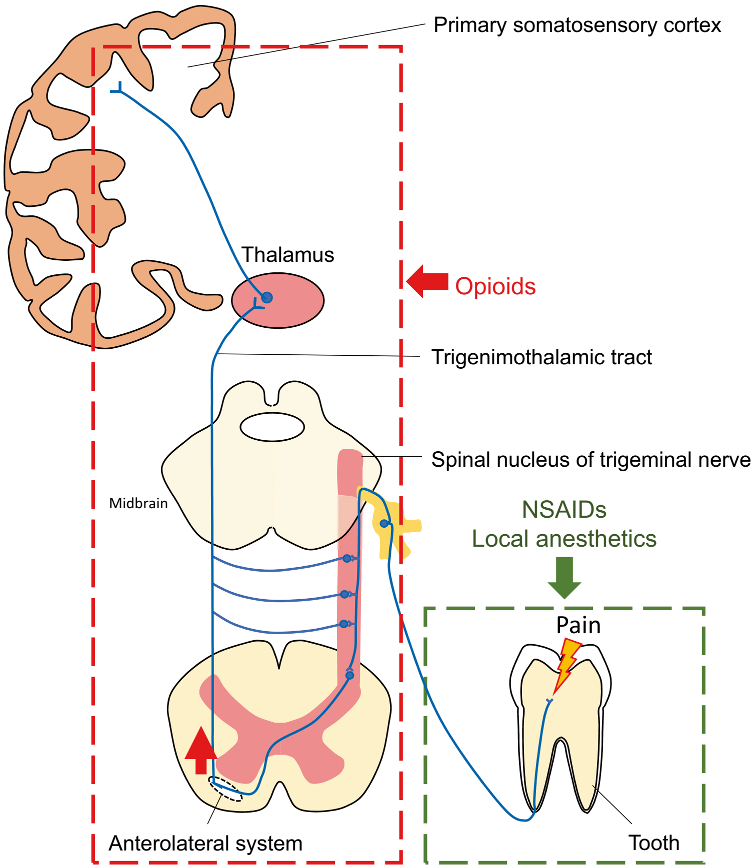


Fig. 14.3 Tooth pain transmission pathways and sites of action of analgesic such as NSAIDs and opioids. When nociceptors are stimulated, electrical signals are transmitted through the primary neurons to the dorsal horn of the spinal cord. The electrical signals are transmitted to secondary neurons via synapses and then to the hypothalamus. There, they are transmitted to tertiary neurons and projected to the somatosensory cortex of the cerebral cortex. On the other hand, the nerves from the brainstem to the dorsal horn of the spinal cord inhibit excessive electrical signals (descending pain inhibitory system) (Mesbah et al. 2016; Todd 2010)

Table 14.4 Adverse events of opioids and NSAIDs. Opioids have serious risks such as addiction and abuse

Opioids	NSAIDs
Risks of addiction, abuse, and overdose	Digestive tract disorder
Tolerance	Renal disfunction
Physical dependence	Bronchial asthma
Respiratory depression	Cardiovascular disorder
Constipation	Increased bleeding
Nausea, vomiting	Anaphylactoid reactions
Dry mouth	
Sleepiness and dizziness	
Confusion	
Mood alternation (euphoria/dysphoria)	
Increased sensitivity to pain	

Steinmetz et al. 2017). Secondly, dental treatment is closely related to opioid exposure in young adult people. The percentage of patients aged 11 to 25 years who have received opioid prescriptions from a dentist was significantly higher at 23.5% compared to 16.4% of patients aged 26 to 64 years (Gupta et al. 2018). A common source of opioid exposure in dentistry for young adult people is for pain relief after third molar extractions (Schroeder et al. 2019; Weiland et al. 2015). A retrospective investigation of young adult showed that patients who used opioids after dental treatment had higher rates of opioid abuse or overdose than patient who used other than opioids (Schroeder et al. 2019). In particular, a study of opioid use before and after high school graduation showed that those with history of an opioid prescriptions before graduation had 33% higher risk of misuse than those with no history of opioid prescriptions (Miech et al. 2015).

Thus, the easy use of opioids in dentistry should be avoided. A panel formed by clinical experts, patients, academic institutions, administered health facilities, and practice unanimously agreed that opioids use be reduced as much as possible of the dental treatment. Especially, the panel recommended that opioids use be stopped for 6 of 14 procedures (43%), which included tooth extractions, osseous procedures, flap procedures, and soft tissue procedures (Farooqi et al. 2020). Dental pain can often be controlled with non-opioid analgesics such as acetaminophen and NSAIDs and can also be improved with proper dental treatment. Only when severe pain unresponsive to acetaminophen or NSAIDs is present, consider the use of opioids. When used, the dosage and duration should be kept to a minimum. When the pain is relieved, it should be immediately changed to a non-opioid analgesic and not be used indiscriminately (Gupta et al. 2018; Koepke et al. 2018). In addition, post-treatment pain can be significantly reduced by using a sufficient amount of local anaesthetic. Changing to a long-acting local anaesthetic or using nerve blockade in addition to infiltration anaesthesia can provide long-lasting pain relief and buy time for the analgesic to work (Lieblich et al. 2021; Camps-Font et al. 2020; Li et al. 2020).

Tramadol

Tramadol is one of opioid analgesics. It inhibits reuptake of serotonin and noradrenalin and serves as a partial agonist of μ-opioid receptor (Shaik et al. 2010). The analgetic effect of tramadol is one-tenth of morphine. According to the WHO Cancer Pain Treatment Guidelines, tramadol is classified into the weak opioid analgesics that are used for the second-degree pain (Wiffen et al. 2017). However, in terms of a pain after extraction of a tooth, the analgetic effect of tramadol alone is lower than those of the NSAIDs. On the other hand, the risk of side effects such as nausea, vomiting, and dizziness is higher (Isiordia-Espinoza et al. 2014). To enhance the analgetic effect of tramadol, it is preferable to use it in combination with a NSAID or acetaminophen (Suthakaran et al. 2017).

Table 14.5 Recommended drugs for severity of dental pain

Severity of pain	Recommended drugs
Mild	Ibuprofen 200–400 mg, 3–4 times a day, max 3200 mg/day Acetaminophen 400–600 mg, 3–4 times a day, max 4000 mg/day
Moderate	Ibuprofen 400–600 mg, 3–4 times a day, max 3200 mg/day Diclofenac 25–50 mg, 2–3 times a day, max 150 mg/day Loxoprofen 60–120 mg, 2–3 times a day, max 180 mg/day Acetaminophen 600–1000 mg, 3–4 times a day, max 4000 mg/day
Severe	Acetaminophen 500 mg + ibuprofen 400–600 mg, 3–4 times a day Acetaminophen 325 mg + tramadol 37.5 mg, 4 times a day Acetaminophen (iv) 1000 mg, 3–4 times a day, max 4000 mg/day Flurbiprofen (iv) 50 mg, 2–3 times a day, max 300 mg/day

Approach for Dental Pain

To choose the appropriate analgesics, dentists should consider both the benefits and the risks. Ibuprofen and acetaminophen are mentioned as a drug that has a good balance of benefit-risk (Table 14.5) (Kim and Seo 2020; Halling et al. 2018). Ibuprofen 200–400 mg every 4 to 6 hours can improve mild dental pain. Within this dose range, ibuprofen has a low likelihood to cause side effects. To provide greater pain analgesic, increase the dose of ibuprofen to 400–600 mg. It is also possible to switch to other NSAIDs such as etodolac, diclofenac, and loxoprofen (Halling et al. 2018; Hollingworth et al. 2017; Masa et al. 2006). In fact, NSAIDs other than ibuprofen are widely used in some countries. However, the risk of side effects increases as the dose increases (Kim and Seo 2020).

Acetaminophen is less likely to cause side effects than NSAIDs but is also less effective for pain relief. Therefore, acetaminophen should be administered at a dose of about 400–1000 mg (4000 mg per day) to achieve full effectivity for pain relief. In addition, together with a NSAID, opioid analgesic is also recommended such as ibuprofen and tramadol (Kim and Seo 2020; Bailey et al. 2013). If the pain is severe or difficult to internal use, transvenous administration should be considered such as flurbiprofen and acetaminophen (Wang et al. 2020).

Analgesics Combination Therapy

Combination therapy has often been shown to be more effective at controlling postoperative pain after third molar extraction. Four main reasons have been proposed to explain this phenomenon. The first is that analgesic agents with different mechanisms of action may have additive effect. The second is that one of the analgesic agents may affect the pharmacokinetics of the other, which may cause higher plasma concentrations and greater efficacy of the medications. The third possibility is one agent alters the nociceptive sensitivity of the other agent. The fourth reason is genetic variations in sensitivity and metabolism may cause one patient to response

better to one analgesic agent than another. A popular analgesic combination is an opioid with acetaminophen, such as acetaminophen-hydrocodone and acetaminophen-oxycodone. Another popular combination is ibuprofen-acetaminophen, which has been shown to be more effective than monotherapy which each analgesic agent and at least as effective as opioid- acetaminophen combinations. The combination of ibuprofen and acetaminophen has also been shown to have a lower incidence of adverse reactions such as nausea, vomiting, headache, or dizziness. If severe pain is anticipated, opioid could be added to the ibuprofen-acetaminophen regimen for breakthrough pain. Currently, a combination dose of oral ibuprofen 400–600 mg with oral acetaminophen 500 mg is recommended for moderate to severe pain, with hydrocodone 10 mg PRN.

Corticosteroids

Corticosteroids are a class of medication that inhibits inflammation by inhibiting phospholipase 2. This inhibits the production of prostaglandins, leukotrienes, and thromboxane 2. Inhibition of these products can reduce the symptom of pain associated with inflammation. As a result, corticosteroids can be viewed as analgesic adjuvant. Corticosteroids are divided into two main groups, glucocorticoids and mineralocorticoids. Glucocorticoids are mainly administered for third molar extractions since they do not have much of an effect on fluid and electrolyte balance. Glucocorticoids vary in potency and duration of action, as shown in Table 14.6.

The most prescribed glucocorticoids for third molar extractions are oral dexamethasone and oral methylprednisolone. Some providers may also administer intravenous or intramuscular dexamethasone. A systemic review suggests that dexamethasone and methylprednisolone delivered intravenously or intramuscularly in the preoperative period are most effective for reducing inflammation and pain. However, the most convenient route of administration is orally. A study has shown that administration of oral dexamethasone can be as effective as intravenous administration. However, oral administration of can cause stomach upset. Further research is still needed to find the best route, dosage, and timing to maximize the analgesic effects of corticosteroids.

Table 14.6 The anti-inflammatory potency and duration of action of glucocorticoids

Glucocorticoids	Anti-inflammatory potency	Duration of action
Cortisol	1	Short (<12 h)
Cortisone	0.8	
Prednisone	4	
Prednisolone	4	Intermediate (12–36 h)
6-Methyl prednisolone	5	
Triamcinolone	5	
Dexamethasone	25	Long (> 36 h)
Betamethasone	25	

Role of Antibiotics in Postoperative Pain

The extraction of teeth always carries risks of infection, which can cause pain, fever, swelling, trismus, and abscess. There are also risks of alveolar osteitis (dry socket), a painful condition that occurs when a blood clot fails to form over the extraction socket. Fortunately, the incidence of postoperative infection is relatively low. However, many dentists and oral surgeons still prescribe prophylactic oral antibiotics, especially for complex surgical extractions and those with systemic conditions. These prescribed oral antibiotics include amoxicillin (with or without clavulanate), clindamycin, erythromycin, and metronidazole. The course and dose of antibiotic differ between providers. Some studies have shown that prophylactic antibiotic can reduce risk of infection and postoperative pain. A large meta-analysis review has found there may be no difference between antibiotics and placebo for pain. It did find that treating "19 healthy patients with prophylactic antibiotics may prevent one infection". However, due to the low rate of infectious complications and increased risk of mild adverse effects from antibiotics, the authors of the study ultimately do not recommend healthy people with surgical extraction of third molars to get regular prophylactic antibiotics.

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The Negative Effects of Surgery with Sensory Nerve Injury Due to Mandibular Third Molar Extraction on the Quality of Life

15

Tatsuo Okui and Joe Iwanaga

Introduction

Sensory nerve injury is the most important potential postoperative complication of third molar removal; it can also occur during dental injection. Pain, swelling, and other complications caused by surgical invasion decrease with time, but paraesthesia and other neuronal impairments can remain for a long period. A nerve injury that is associated with third molar extraction can cause taste impairment and sensory loss in the tongue. Such long-term complications can affect the patient's quality of life.

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The Incidence of Neurosensory Impairment After Third Molar Extraction

Neurosensory impairment is one of the most distressing complications of mandibular third molar extraction. Studies of the outcomes of third molar extraction have focused on extraction criteria and their complications, but the effects that a third molar extraction has on the patients' quality of life (QOL) during the postoperative period have not been well investigated (Sancho-Puchades et al. 2012).

Regarding the factors involved in patients' satisfaction after third molar extraction, Lee et al. (2015) observed that satisfaction was greater among the patients who had noncomplicated surgery, short treatment times, and no post-surgery emergency appointments. Approximately 9% of their patients had post-surgery emergency appointments, and the three most common reasons for the appointments were post-operative severe pain, followed by swelling and bleeding. It is not yet clear how symptoms such as paraesthesia, pain, and swelling detract from patients' satisfaction and QOL.

QOL Assessments for Patients Who Have Undergone a Third Molar Extraction

For an assessment of patients' Oral Health-Related Quality of Life (OHRQOL), Slade (1997) measured the functional, social, and psychological outcomes of oral conditions based on a 49-question survey known as the Oral Health Impact Profile (OHIP)-49. The OHIP-49 was later improved as a short form with 14 questions (the OHIP-14) which has shown good reliability, validity, and precision. The 14 items are divided into 7 parts: functional limitation, physical discomfort, psychological discomfort, physical disability, psychological disability, social disability, and handicaps. The OHIP-14 has been used worldwide for various research purposes with modifications including language and regional concerns (Shugars et al. 2006) (Table 15.1).

However, there has been little information about patients' QOL after the removal of a third molar. Oral surgeons need more knowledge about post-surgery QOL in order to better inform their patients, particularly as there is evidence suggesting that patients want to know more about the effects of third molar extraction on potential QOL impairment. In their review, Duarte-Rodrigues et al. (2018) stated that the highest negative impact on QOL of third molar extraction was observed on the day following the extraction and decreased over the follow-up period, with physical pain being the most common symptom. Eating disability, speech disability, and pain are correlated with patient QOL after third molar extraction, but these symptoms disappear within 1–2 weeks (Grossi et al. 2007). In contrast, sensory disturbance remains for a long time. For this reason, sensory dysfunction and/or paraesthesia are the most important negative factors in patients' long-term QOL.

Similarly, Ruta et al. (2000) reported that paraesthesia of the lips and tongue after third molar extraction is the most significant QOL factor as evaluated by their

Table 15.1 List of questions on OHIP-14 questionnaire

1	Have you had trouble pronouncing any words because of problems with your teeth or mouth
2	Have you felt that your sense of taste has worsened because of problems with your teeth or mouth
4	Have you found it uncomfortable to eat any foods because of problems with your teeth or mouth
5	Have you been self-conscious because of your
6	Have you felt tense because of problems with your teeth or mouth
7	Has been your diet been unsatisfactory because of problems with your teeth of mouth
8	Have you had to interrupt meals because of problems with your teeth or mouth?
9	Have you found it difficult to relax because of problems with your teeth or mouth
10	Have you been a bit embarrassed because of problems with your teeth or mouth
11	Have you been a bit irritable with other people because of problems with your teeth or mouth
12	Have you had difficulty doing your usual jobs because of problems with your teeth or mouth
13	Have you felt that life in general was less satisfying because of problems with your teeth or mouth
14	Have you been totally unable to function because of problems with your teeth or mouth

postoperative symptom severity scale (PoSSe), which is based on questions that are commonly used in the clinical assessment of patients who have had a third molar extracted. Kim et al. (2010) observed that postoperative anxiety, pain, infection, and numbness/paraesthesia have a significant influence on patient satisfaction. Paraesthesia in particular was an independent predictive factor of lower patient QOL. Interestingly, the mental health component in QOL was significantly affected when a permanent nerve injury was present, although the physical health component was not much affected (Leung 2019).

The Management of Neurosensory Impairment

The injury of a peripheral nerve leads to neural sheet oedema and microcirculation disturbances due to traumatic inflammation. To control inflammatory reactions in the injured nerve, a course of oral steroids can be prescribed. Oral dexamethasone can be used. As an alternative or adjunct, a 4-week regimen of a high dose of a non-steroidal anti-inflammatory drug (NSAID) could be used. If the patient's symptoms and condition do not improve, another course of anti-inflammatory drugs can be administered. Perceptions of pain and temperature are usually the first two sensations to recover, whereas other sensations may take longer.

Evidence regarding the appropriate time for a clinical nerve repair intervention is lacking. In cases in which there has been little effect by drug treatment within 10–12 weeks post-surgery, management options including microsurgical nerve reconstruction within a short period should be considered as a treatment plan.

As summarized in Table 15.2, sensory neuron traumatic damage can be classified into the following three grades: (1) Neuropraxia is a conduction block without

Table 15.2 Sensory neuron traumatic damage

	Neurosensory impairment	Recovery potential
Neuropraxia	Neuritis, paraesthesia	Full (1 day to 2 months)
Axonotmesis	Paraesthesia, dysaesthesia, hypoaesthesia	2-12 months
Neurotmesis	Anaesthetic, intractable pain, neuroma formation	None

axonal degeneration that can heal spontaneously. (2) Axonotmesis is an injury with a loss of continuity of axons, but regeneration can take place several months later without surgical intervention. (3) Neurotmesis is the most severe injury and requires microsurgical intervention (Seddon 1942). The effect of early repair on functional sensory recovery has been a matter of controversy. A recent meta-analysis by Suhaym and Miloro (2021) revealed neuron repair success rates of 93.0% for early-repair patients and 78.5% for late-repair patients, and Suhaym and Miloro reported a trend towards early repair achieving better functional sensory recovery outcomes.

In an earlier paper, Elfring et al. (2014) indicated that the transection of a lingual nerve was associated with difficulty in swallowing and social contact and that fewer problems were reported when these nerves were either repaired or left intact.

Age, Sex, and Ethnic Group Differences in Pain Sensitivity and Taste

Differences in pain, taste disability, and post-surgery QOL among patients of different ages, sex, and ethnic groups have been reported. For example, Yoshinaka et al. (2016) observed that young adults had significantly lower taste recognition thresholds compared to older adults, and the women had significantly lower recognition thresholds for sour, salty, and bitter tastes compared to the men. In another study, Asians were found to be more sensitive to the same tastes compared to Caucasians (Yang et al. 2020).

Over the past 15 years, there has been a systematic effort to understand differences in experiencing pain among patients in various ethnic groups. Komiyama et al. (2012) found that Japanese subjects were more sensitive to pain than Caucasian subjects, and women were more sensitive to pain stimulation compared to men. Interestingly, ethnic differences were also present in that study regarding the exteroceptive suppression reflex in the masseter muscle: compared to the Japanese subjects, the Caucasian subjects required less electrical stimulation to produce a masseteric exteroceptive suppression reflex, and they had a longer suppression period and greater degree of suppression.

Kim et al. (2019) reported that compared to non-Hispanic white (NHW) patients, African American patients had lower heat pain tolerance and higher suprathreshold pain ratings; in addition, Asian patients had higher suprathreshold pain ratings, lower heat pain tolerance, and a lower mechanical cutaneous pain threshold

compared to NHWs. This is an interesting finding, as it indicates that a sensory nerve injury may not cause the same decline of QOL among patients of different sex, age, and ethnic groups. Future studies of the decline in patients' quality of life due to an inferior alveolar nerve injury or lingual nerve injury associated with a third molar extraction should therefore be multinational.

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Mandibular Third Molar Extraction and General Anaesthesia

16

Naotaka Kishimoto and Kenji Seo

Introduction

It is difficult to evaluate the effects of the anaesthetic modality alone on nerve damage. Moreover, rare complications, such as laryngeal paralysis and subcutaneous emphysema, after third molar extraction under general anaesthesia can also occur. This chapter describes the indications for mandibular third molar extraction under general anaesthesia and its complications. We also discuss the complications of both general anaesthesia and mandibular third molar extraction.

Indications of the General Anaesthesia for Mandibular Third Molar Extraction

Patient Factors

Although most dental patients can undergo surgery under local anaesthesia, a significant number of patients require intravenous sedation or general anaesthesia owing to anxiety of the surgery (Edwards et al. 1998). According to a study that analysed 29,548 adolescent patients in the Oral and Maxillofacial Surgery Outcomes System developed by The American Association of Oral and Maxillofacial Surgeons, patients undergoing tooth extraction under general anaesthesia/deep sedation had significantly higher preoperative anxiety scores than those under moderate sedation (Inverso et al. 2016). A study that evaluated patients' stress response levels by measuring salivary cortisol concentrations reported that patients undergoing mandibular third molar extraction under local anaesthesia had lower stress response levels than

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those under general anaesthesia (Hill and Walker 2001). These results imply that general anaesthesia is used for mandibular third molar extraction in patients with severe preoperative anxiety. Unfortunately, performing mandibular third molar extraction under general anaesthesia carries the risks of anaesthesia-related morbidities and, rarely, mortality (Hong and Birnie 2016). Serious morbidities include arrhythmias, liver damage, and hypoxia, whereas common morbidities include nausea, vomiting, headache, and drowsiness. Moreover, psychological problems such as psychological trauma, nightmares, and depression have been reported in children aged 5–15 years undergoing tooth extraction under general anaesthesia, albeit with low frequency (Bridgman et al. 1999). Therefore, the choice of anaesthetic modality should not simply be dictated by the patient's preference alone, but it is recommended to also refer to the guidelines for standards of care in dental general anaesthesia published by the General Dental Council (GDC), the Royal College of Anaesthetists (RCA), and the Department of Health (DOH) (Sammut et al. 2013). These guidelines state that, in consideration of its risk, general anaesthesia for dentistry should be limited to certain patients, as shown in Table 16.1 (Flynn and Strunin 2005). The GDC also recommends considering other methods for controlling patients' pain and anxiety before choosing general anaesthesia (Sammut et al. 2013). One of the methods is conscious intravenous sedation, which is more cost-effective than general anaesthesia (Jameson et al. 2007) and can reduce postoperative morbidity (Brann et al. 1999). According to a study investigating anaesthetic modalities for single tooth extraction (excluding impacted mandibular teeth) in adult patients at the Royal Cornwall Hospitals NHS Trust (RCHT), UK, general anaesthesia was often selected in accordance with the patient's request rather than the clinical need. The authors devised the case selection criteria presented in Table 16.2 to avoid making inappropriate anaesthetic choices and wasting resources, such as staff salaries and theatre time (Hong and Birnie 2016).

As per the studies evaluating patient deprivation status using the Scottish Index of Multiple Deprivation (Sammut et al. 2013) or the English Index of Multiple Deprivation (Hong and Birnie 2016), patients from more deprived areas are more likely to choose general anaesthesia when undergoing tooth extraction than those from wealthy areas; the reason for this remains unknown. However, it is important to note that these studies were conducted in the UK where medical expenses are covered by the National Health Service, and thus in principle, there is no out-of-pocket payment by the patient. In contrast, the medical cost for extracting two impacted

Table 16.1 Criteria for patients receiving general anaesthesia for dentistry (Flynn and Strunin 2005)

Patients who are unable to cooperate owing to immaturity or physical or mental disability
Patients in whom local anaesthesia has repeatedly proved unsuccessful or is unlikely to be completely effective owing to the extent of surgery or the presence of infection
Patients with a history suggestive of hypersensitivity or allergy to the contents of the local anaesthesia ampule
Patients who suffer from extreme nervousness and who refuse to undergo any form of dental treatment while conscious

Table 16.2 Dental extraction under general anaesthesia case selection criteria (Hong and Birnie 2016)

Physical, emotional, or learning impairment
Medical problems that are better controlled with the use of GA
Severe trismus and cases that require incision and drainage
Complex operative procedure (e.g. surgical removal of deeply impacted teeth)
Procedure expected last for ≥40 min (single slot)
Failure of extraction using other modalities at RCHT
Allergy or any contraindication to LA

GA general anaesthesia, *RCHT* Royal Cornwall Hospitals NHS Trust, *LA* local anaesthesia

mandibular third molar under general anaesthesia in the USA is estimated to be USD 1,184 (Koumaras 2012). Although the out-of-pocket amount varies depending on the type of insurance the patient has, the financial condition of individual patients may influence the anaesthetic modality more in the USA than in the UK.

Surgeon Factors

General anaesthesia is usually selected preoperatively in cases of tooth extraction deemed difficult by the surgeon. According to Edward et al., surgical difficulty is the most significant factor that influences the anaesthetic modality, followed by patient anxiety, patient preference, and medical history (Edwards et al. 1998). Costantinides et al. investigated the anaesthetic modality in 534 patients undergoing mandibular third molar extraction. They reported that, compared with the local anaesthesia group, the general anaesthesia group had more third molars with higher Pell and Gregory Classification and had a significantly higher number of patients requiring surgeries such as tooth sectioning and osteotomy (Costantinides et al. 2016). Further, in two studies investigating the anaesthetic modality in patients undergoing mandibular third molar extraction, the general anaesthesia group had a significantly higher number of cases with high surgical difficulty evaluated by the WHARFE score than the local anaesthesia group (Edwards et al. 1999) (Sammut et al. 2013). General anaesthesia tends to be selected in cases of high surgical difficulty at the authors' university (Niigata University, Japan) as well. Such cases are expected to be more invasive and have longer operation times, and thus, general anaesthesia is expected to reduce these burdens on the patients (Uematsu et al. 2015).

Rehman et al. proposed a method to evaluate the difficulty level using the visual analogue scale (VAS) from the findings of panoramic radiographs because using the WHARFE score to evaluate surgical difficulty has not been validated (Rehman et al. 2002). They investigated the anaesthetic modality for mandibular third molar extraction in 391 patients and reported that neither the WHARFE score nor the VAS score was significantly different between the general and local anaesthesia groups, even reporting that the degree of surgical difficulty was similar. Hill et al. analysed 54 patients undergoing mandibular third molar extraction and reported that, although the sample size was small, no significant differences in the WHARFE score or surgical time between the general and local anaesthesia groups were noted (Hill and Walker 2001).

Table 16.3 Criteria for cases to be indicated for wisdom tooth extraction under general anaesthesia proposed by the authors

Patients with severe anxiety and fear of tooth extraction and are difficult to control under intravenous sedation
Patients who are allergic to local anaesthetics or in whom local anaesthesia has repeatedly proved unsuccessful
Patients who are uncooperative with surgery owing to immaturity or mental disability
Cases that have high surgical difficulty and long operation time as determined the surgeon

We should also consider the effect of a surgeon's grade on the anaesthetic modality. Sammut et al. investigated the anaesthetic modality alongside the grade of the surgeon (consultant, staff grade, and trainee) who performed the mandibular third molar extraction. Both consultants and staff grades had higher proportions of general anaesthesia cases than trainees (Sammut et al. 2013). Conversely, consultants often choose tooth extraction under local anaesthesia compared with other clinicians (Edwards et al. 1998). Unfortunately, neither of the above conflicting reports discussed why these results were obtained. Hence, further research is warranted on the effect of a surgeon's grade on the anaesthetic modality.

The differences in institutions can also influence the anaesthetic modality. In a study conducted in the UK that analysed the anaesthetic modality in mandibular third molar extraction, general anaesthesia was significantly more often selected in the oral and maxillofacial unit of a district general hospital than in an oral surgery outpatient facility (Sammut et al. 2013). Similarly, Kim et al. reported that hospital-based maxillofacial units more frequently select general anaesthesia for mandibular third molar extraction in the UK, whereas smaller units where access to theatre facilities is difficult choose local anaesthesia and intravenous sedation more frequently (Kim et al. 2006).

In summary, patients tend to choose general anaesthesia for mandibular third molar extraction owing to anxiety and fear, whereas surgeons choose the anaesthetic modality based on surgical difficulty and accessibility of the technique at their institution. Table 16.3 lists the indications for third molar extraction under general anaesthesia proposed by the authors.

Complications of Mandibular Third Molar Extraction Under General Anaesthesia

For the complications of general anaesthesia and mandibular third molar extraction, please refer to each textbook or the description in another section of this book. This section introduces complications that occur (or are suspected) in both.

Nerve Injury

Brann et al. investigated nerve injury during mandibular third molar extraction in 367 patients. Among those in the general anaesthesia group, 8% had an inferior alveolar nerve (IAN) injury, and 12% had a lingual nerve (LN) injury. In the local

anaesthesia group, none had IAN injury, but 3% had LN injury. The general anaesthesia group had a significantly higher incidence of nerve injury than the local anaesthesia group. However, the surgical difficulty evaluated by the WHARFE score was not different between the two groups. Although the exact cause remains unknown, it is speculated that the surgery was complicated by the following factors: (1) patients being in the supine position during general anaesthesia, (2) the extent of mucoperiosteal stripping and bone removal, (3) stronger surgical force under general anaesthesia compared with that under local anaesthesia, and (4) the tendency of surgeons to limit soft tissue retraction and surgical force under local anaesthesia (Brann et al. 1999). Costantinides et al. investigated nerve injury during mandibular third molar extraction performed by the same surgeon in 534 patients. In the general anaesthesia group, 4.6% had IAN injury, whereas 2.1% had LN injury. In the local anaesthesia group, 0.3% had IAN injury, whereas none had LN injury. IAN and LN injuries were significantly more common in the general anaesthesia group than in the local anaesthesia group. These results are thought to be because only a few of the third molar extracted under general anaesthesia were normally erupted and the surgical difficulty was high (Costantinides et al. 2016).

As discussed above, some reports found that the incidence of nerve injury increases in patients undergoing mandibular third molar extraction under general anaesthesia, but other reports claim that there is no difference between general and local anaesthesia. Rehman et al. investigated nerve injury during mandibular third molar extraction in 391 patients. In the general anaesthesia group, 2.44% of the patients had IAN injury, whereas 3.58% had LN injury. In the local anaesthesia group, 0.8% of the patients had IAN injury, whereas 0.65% had LN injury. Although the frequency of nerve damage appears to be high in the general anaesthesia group, logistic regression analysis revealed no significant relationship between the anaesthetic modality and nerve injury. The two groups also had no differences in surgical difficulty as evaluated by the WHARFE and VAS scores (Rehman et al. 2002). Hill et al. also investigated nerve injury during mandibular third molar extraction in 435 patients and reported that the incidence of LN injury was ≤5% in both the general and local anaesthesia groups, with no difference in the frequency (Hill et al. 2001).

There are several conflicting reports on the effects of anaesthetic modality on nerve injury during mandibular third molar extraction, and it remains unclear whether general anaesthesia is associated with nerve injury. Uematsu et al. recommend general anaesthesia for cases at high risk of nerve injury, such as those wherein the IAN and third molar are in close proximity. This is because the surgical field cannot be sufficiently secured and instrument operation is restricted under local anaesthesia, whereas a wide surgical field can be secured and nerve exposure can be easily confirmed under general anaesthesia (Uematsu et al. 2015). Hence, experts have varied opinions on this topic. Moreover, many factors such as surgical difficulty (Costantinides et al. 2016), surgical time (Hill et al. 2001), the surgeon's experience (Blackburn and Bramley 1989), and presence of an abscess in the mandibular third molar (Costantinides et al. 2009) affect postoperative nerve injury, which makes it difficult to evaluate the effects of anaesthetic modality alone on nerve damage.

More Time Off Work After Surgery

Edwards et al. investigated the impact of mandibular third molar extraction on the lives in 266 patients. In patients who had tooth extractions under general anaesthesia, the postoperative time off work was 5.7 ± 4.4 days (mean ± SD), which was significantly longer than the 2.9 ± 2.6 days of those who had tooth extractions under local anaesthesia. Furthermore, significantly more patients who underwent third molar extraction under inpatient general anaesthesia availed primary care services (i.e., general practitioner, general dental practitioner, and hospital emergency department) owing to pain, discomfort, infection, and numbness compared with those who underwent tooth extraction under local anaesthesia (Edwards et al. 1999). Because general anaesthesia is more often used in cases with a high WHARFE score, it is presumed that surgical invasion was greater in patients in the general anaesthesia group and that they took more time for postoperative recovery.

Laryngeal Paralysis

Koshika et al. reported a case of a 31-year-old male patient who developed paralysis of the bilateral glossopharyngeal nerve, vagus nerve, right recurrent laryngeal nerve, and right hypoglossal nerve, followed by aspiration pneumonia due to dysphagia after mandibular third molar extraction under general anaesthesia. Tracheal intubation after inducing general anaesthesia was not difficult, and tracheal tube cuff pressure was continuously monitored at 20–25 cmH_2O. In oral surgeries under general anaesthesia, factors such as frequent position changes of the head and neck, compression of the vocal cord tissue with the tracheal tube, excessive compression of the tracheal tube cuff, excessive compression with pharyngeal packing, and use of the tongue depressor can cause postoperative neuropathy. The exact mechanism of the onset of laryngeal paralysis in this case is unknown, but it is speculated to be due to a combination of some of the above causes (Koshika et al. 2020).

Subcutaneous Emphysema

In a case of mandibular third molar extraction under general anaesthesia, compressed air from the air turbine dental handpiece used to divide the tooth was found to invade from around the third molar, causing subcutaneous emphysema in the ceramic region and mediastinal emphysema (Magni et al. 2008) (Capes et al. 1999). These are some complications that accompany tooth extraction procedures. However, Kawahara et al. pointed out that compressed air may easily invade from around the third molar because many cases of tooth extraction under general anaesthesia have high surgical difficulty, and thus the range of incision and peeling is increased to clarify the surgical field (Kawahara et al. 2013).

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Other Evidence for the Mandibular Third Molar Extraction

17

Daniel Shen, Quang Do, Keiko Fukino, and Hiroe Ohyama

Introduction

Evidence regarding the complications for mandibular third molar extraction has been discussed in other chapters. There are different devices and techniques that might improve the postoperative patient QOL. In this chapter, we will discuss the evidence of different methodologies used during the extraction of the mandibular third molar.

Mandibular Third Molar Extraction and Sedation

Sedation is a key component when it comes to third molar extractions. The choice of sedation is based on the patient's need and health as well as the operator's preference. Although there are different pharmacological agents for achieving the same

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sedation effects, the ideal agent used in outpatient practices should have the following three key properties: rapid onset of action, stable operating conditions, and easy reversibility (Goodchild and Donaldson 2005). Midazolam which provides anxiolysis, anterograde amnesia, and sedation and fentanyl which offers analgesia are two of the most commonly used agents that have the properties listed above. Recent studies have investigated the order of application of these two agents and their influence on recollected procedural pain scores after third molar extraction, and it was concluded that this had no bearing on pain perception (Khader et al. 2015).

In addition to midazolam, other benzodiazepines such as diazepam have also been used for sedation in third molar extractions. When comparing the usage of midazolam versus diazepam in sedation procedures for third molar extractions, there were no differences in their effectiveness in controlling the anxiety of patients and little effect on vital signs and retrograde amnesia (de Moares et al. 2019).

As for fentanyl, there has been recent investigations in the usage of remifentanil, which is a short-acting narcotic that is chemically related to the fentanyl family. However, it differs from fentanyl due to its ester linkage which makes it susceptible to plasma and tissue esterase degradation. This allows remifentanil to be rapidly metabolized to essentially inactive metabolites. Remifentanil also leads to a lower peak heart rate and systolic blood pressure levels which may indicate less fluctuation in cardiovascular parameters when compared to fentanyl or meperidine that is more long-acting when compared to remifentanil. Ultimately, the usage of remifentanil may provide benefits for patients with cardiovascular compromise (Ganzberg et al. 2002).

Ultrasonic Devices

The use of ultrasonic devices for oral surgery-related purposes dates back to 1988 with use by the Italian oral surgeon Tomaso Vercellotti (Pavlikova et al. 2011). Since then, the use of ultrasonic surgical devices has gradually expanded in its applications within the realm of oral and maxillofacial surgery including sinus augmentations and surgical extraction of the teeth.

Piezoelectric bone surgery (PBS) is a technique that takes advantage of the micrometric cuts produced by the instrument to minimize the surface area of the bone affected and thermonecrosis of the bone around the surgical site. With an oscillation frequency of 24–32 kHz, the instrument prevents the use of excessive operator force to produce precise osteotomies that are selective for mineralized structures to overall prevent iatrogenic damage to surrounding soft tissues. In numerous commercial devices, the oscillating tip provides an irrigating solution while operating to allow proper visibility and removal of debris that may have been generated during the procedure (Barone et al. 2010). In addition, PBS has shown a more favourable osseous healing response in contrast to the conventional osteotomy performed by diamond or carbide burs due to improved cellular reactivity (Vercellotti et al. 2006). Although there are reported concerns surrounding prolonged operator time, overheating of the instruments, and malfunction of the ultrasonic tip,

promising surgical results were found in a meta-analysis performed by Badenoch-Jones et al. investigating the clinical outcomes of using ultrasonic devices for the extraction of mandibular third molars. Results from the meta-analysis suggest a decrease in postoperative pain, trismus, facial swelling, and neurological complications after the removal of mandibular third molars that required osteotomies (Badenoch-Jones et al. 2016). In another systemic review and meta-analysis conducted by Cicciu et al. comparing conventional rotary instruments and PBS, it was concluded that although there was a longer duration of surgery, the postoperative morbidity of pain and trismus was significantly lower in the PBS group. As for neurological complications, the meta-analysis showed that there were no differences between rotary instruments and PBS (Cicciù et al. 2021).

Late Incisor Crowding

Many dentists believe that the impacted mandibular third molar, especially the horizontally impacted mandibular third molar, indirectly might push the incisors that results in the late incisor crowding which is observed as a crowding of the mandibular incisors at 13 to 26 years. During this period of age, the mandibular third molars erupt, and the roots are formed. There is a number of studies which investigated this correlation, but it is still controversial if the impacted mandibular third molar contributes to the late incisor crowding (Zigante et al. 2021).

Low-Level Laser Therapy

Low-level laser therapy (LLLT) was initially explored to serve as a medium to eradicate malignant cells. Instead, it was observed to increase the growth of Ehrlich ascites tumour and fur in mice. This phenomenon was further explored finding that LLLT was able to promote the healing of mechanically induced wounds. Repeated exposure led to a faster regeneration that started from the wound edges and eventually led to granulation (Mester et al. 1971). From the advent of this discovery, lasers have been widely applied to dentistry to serve a myriad of purposes including ulcer healing, mucositis, and bone regeneration.

The use of LLLT in third molar extraction surgery serves two main purposes: analgesic and anti-inflammatory effects. LLLT allows postoperative analgesia mainly through the increased production of endogenous endorphins (B-endorphin) and the decrease in activity of C-fibres and bradykinin. In addition, to influencing the pain pathway, LLLTs can cause neural conduction blockage as well through inducing morphological neuronal changes, reducing the mitochondrial membrane potential, and blockage of the fast-axonal flow (Chow et al. 2007). As for the anti-inflammatory benefits that LLLT provides, they are mediated through the inhibition and downregulation of IL-6, IL-10, and TNF-a production in a dose-dependent manner (Boschi et al. 2008). With the aforementioned cytokines decreased, this engenders a surgical site with increased phagocytic activity and number/ diameter

of lymphatic vessels along with a decrease in the permeability of the vascular wall. Overall, this leads to a restoration of micropapillary circulation and normalization of the permeability of the vascular wall to decrease the oedema of the surgical site (Albertini et al. 2007).

There is a diverse range of studies investigating different types of lasers, frequency, wavelength, time, and mode of application which makes any standardization and uniformity difficult. However, more recent studies have focused on the usage of an intraoral laser diode 940 nm immediately postoperatively. Fibre tips of the laser diode were placed in close proximity to the soft tissue after primary closure of the surgical site with sutures. An energy density of 10 J/ 3 cm^2 was applied for 30 s at three occlusal, buccal, and lingual points with a total time of 90 s. With this practice, it was shown that long-term postoperative pain (7 days) was significantly lower in the intervention group (Ferrante et al. 2013). The utilization of 637 nm gallium/aluminium/ arsenic lasers at the surgical site at 4 J/cm^2 for 10 min was also cited to decrease postoperative pain significantly after mandibular third molar extractions, especially when combined with local dexamethasone therapy (Markovic and Todorovic 2007). 810 nm and 11 J/cm^2 of energy through laser diodes has also been studied and proven to statistically lower pain levels and duration (Neckel and Kukiz 2001). Due to the varied parameters of lasers used, wavelength, and energy levels investigated in different studies, it has been extremely difficult to standardize a course of practice to follow the use of LLLT in daily third molar extraction procedures. However, the promising results from a diverse group of studies illustrate the potential application of LLLT for common third molar exodontia practice.

Flap Design and Operation Time

Flap design during third molar extractions is the foundation to proper visibility and access to impacted tooth. These factors allow a decrease of complications that may arise when surgically extracting impacted third molars. Surgical flaps that are currently used include envelope flaps (EF), triangular flaps (TF), modified Wards, and modified triangular flap (MTF) (De Marco et al. 2021; Kumar et al. 2019). Although due to the extent of soft tissue manipulation, it may seem like certain flap designs may be more advantageous over others in terms of postoperative healing, pain, trismus, and swelling, there is no clear evidence or consensus from relevant literature on the benefits of utilizing one flap over the other. Confounding variables including patient management, surgeon's experience, molar position and orientation, and duration of the surgery itself may also influence the postoperative patient experience (De Marco et al. 2021). Out of these variables, the selection of flap design can be most objectively influenced by the molar position and orientation and the desire to decrease the duration of surgery, assuming the operator's skills are standardized.

MTF is often recommended for impacted third molars classified as Class III, Position C using the Pell and Gregory classification. As for the EF, it is indicated for third molars in the Class I Position A location. Similarly based off of the Pederson's scale that defines the level of difficulty of all extractions ranging from easy,

moderately difficult, and difficult, it can determine the preferred flap design. Cases where the preoperative Pederson's scale is defined as easy, the EF approach is often chosen. With moderately difficult to difficult cases, the preferred flap design is TF or MTF in order to allow a wider visibility and larger access to the tooth (De Marco et al. 2021).

The duration of surgery has been reported as the leading factor behind the severity of postoperative side effects (Bello et al. 2011). With a longer operation time, there is an increase in the production of local inflammatory mediators that can sensitize peripheral pain receptors which can upregulate the excitability of the central nervous system neurons. This increase in excitability may ultimately lead to hyperalgesia or allodynia (Lovich-Sapola et al. 2015). Therefore, the usage of a suitable flap design that allows a shortening operation time is vital to decrease postoperative complications. EFs have been reported to require a shorter operation time and result in less tissue trauma with an average reduction of 1.23 min of operation time when compared to TF. With the need to suture the vertical releasing incision with one or more stiches, the TF mainly prolongs surgical time due to an increase in suturing time (Briguglio et al. 2011).

Postoperative Care/Time Off

With the removal of any third molars regardless of difficulty of extraction, postoperative complications include oedema, trismus, inflammation, bleeding, dry sockets, and infection. These complications ultimately alter the course of healing and impact the patient's experiences post-extraction (Shenoi et al. 2021). Investigations have been made to curtail the unfavourable impacts of potential postoperative complications. As mentioned before, LLLT has been placed under scrutiny in its efficacy in reducing pain, trismus, and swelling. However more research with a larger sample size may be needed to fully establish the use of LLLTs in standard practice (He et al. 2015).

In addition to non-pharmacological alternatives, the use of medications, both perioperatively and postoperatively, has been the main channels in facilitating proper postoperative care. Chlorohexidine rinses, topical and systemic antibiotics, pre-emptive corticosteroids, and muscle relaxants are some of the common methods used to prevent or mitigate postoperative complications. In recent years, there have been studies on the use of submucosal injections of corticosteroids after impacted third molar extractions. Meta-analysis studies point to the efficacy of submucosal injections of corticosteroids in reducing oedema in every postoperative phase and trismus early after surgery. However, when it came to minimizing pain and late trismus, there were no strong indications that corticosteroid injections alleviated these complications (Chen et al. 2017).

The use of longer-lasting local anaesthetics such as levobupivacaine and bupivacaine intraoperatively during mandibular third molar extraction is another recent alternative to facilitate postoperative pain control, especially during the periods of most intense pain experienced around 6–8 h after extraction. With the use of these longer-acting analgesics, the goal is to decrease central sensitization and decrease

postoperative analgesic consumption that may lead to unwanted systemic side effects. 0.5% levobupivacaine and 0.5% bupivacaine used as an intermediate anaesthetics after the injections of 2% lidocaine with epinephrine were shown to provide a more pronounced postoperative analgesia and a decrease in analgesic medication consumption (Brajković et al. 2015).

With the onset of the COVID-19 pandemic, there has been a gradual shift in the increase usage of telemedicine appointments if possible, to corroborate the efforts in patient and provider safety. In terms of postoperative appointments for third molar surgeries, the medium of telemedicine was explored for potentially providing a platform for patients to easily access their postoperative appointments. Through a recent study, it was concluded that overall telemedicine and in-office postoperative visits led to similar patient satisfaction; however, patient perceived cost-effectiveness was greater for telemedicine visits than in-person office visits. This was most likely due to the decrease in potential opportunity cost in missing work or the cost associated with traveling/parking (Champion et al. 2021). More research may be needed to further investigate the extent of influence postoperative complications, care, and appointments may play in influencing missed time off from work, but there are studies that site the increase in job disruption and demand on postoperative care from primary care services when general anaesthesia was utilized as the sedation method when extracting third mandibular molars (Edwards et al. 1999).

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Part III

Surgical Techniques

Armamentarium for Mandibular Third Molar Extraction

18

Shoji Ryumon, Puhan He, and Joe Iwanaga

Introduction

Depending on the operator's preference as well as each patient's unique presentation, the instruments utilized for mandibular third molar extraction may differ. In this chapter, we will describe the typical armamentarium for surgical extraction of mandibular third molars.

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Anaesthetic Syringe, Needle, and Local Anaesthetic with Vasoconstrictor

Local anaesthetic, typically 2% lidocaine 1:100,000 epinephrine, is administered mostly commonly using an anaesthetic syringe with a 27-gauge long needle (Fig. 18.1). When delivering local anaesthetic as a nerve block, negative aspiration must be confirmed.

Surgical Scalpel

For the oral mucosal incision and flap design, the all-purpose #15 scalpel blade is the most used. #11 or #12 scalpel blades may be employed as well (Fig. 18.2).

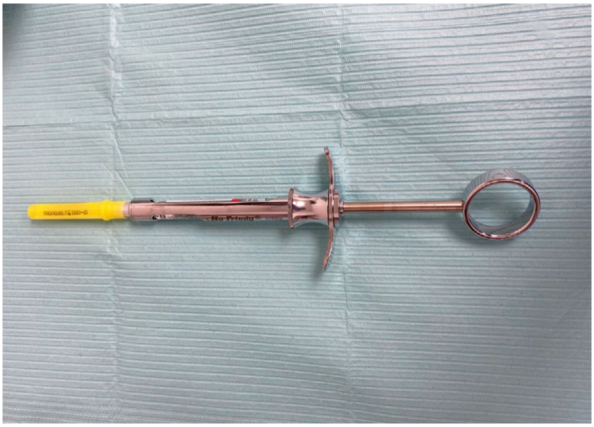


Fig. 18.1 Needle and syringe



Fig. 18.2 Surgical scalpel, from the right to left, blade types #11, #12, and #15



Fig. 18.3 Minnesota cheek retractor

Retractors

Retractors are used to allow for complete visualization of the operative field while protecting the adjacent soft tissue. The *Minnesota cheek retractor* is used primarily to lift and protect the cheek and soft tissues by retracting the mucoperiosteal flap using bone as a fulcrum during the surgical procedure (Fig. 18.3). The *Seldon retractor* is a double ended instrument, with a small spoon on one end and a big spoon on the other (Fig. 18.4). This heavy-duty retractor helps reflect and retract mucoperiosteum from the bone. The *Weider retractor* or better known as the "sweetheart retractor" due to its unique shape and design is used to retract and protect strong muscular tissue like the tongue (Fig. 18.5). The *Hosotani's maxillary retractor*, which is used in the otolaryngology field, is also useful for mandibular third molar extraction (Fig. 18.6).

Bite Blocks

Bite blocks allow the operative field to be visualized and the patient to rest their jaw in the open position. This comes in different sizes for patient comfort and surgical accessibility (Fig. 18.7).



Fig. 18.4 Seldon retractor

Periosteal and Mucosal Elevators

The *Molt #9 periosteal elevator*, which has a spoon-shaped blunt end and a pointy end, is used to reflect the papilla, strip thin mucosal tissue, and separate periosteum from the bone in order to raise a full-thickness mucoperiosteal flap (Fig. 18.8). The *Freer elevator* is a similar tool used to reflect the gingival cuff around each tooth.

Surgical Bur

The surgical carbide burs utilized in the extraction of mandibular third molars include fissure burs and round burs (Fig. 18.9). Either can be used to remove bone to create a buccal trough, while the fissure bur is utilized to section teeth when necessary. Depending on operator preference, a straight surgical handpiece or a contra-angle surgical handpiece can be used.



Fig. 18.5 Weider retractor

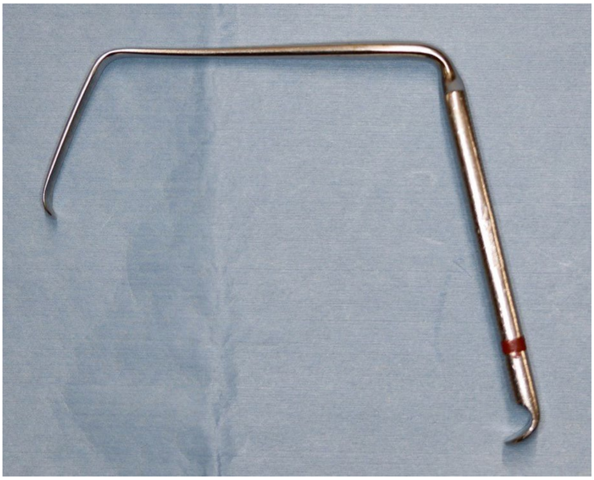


Fig. 18.6 Hosotani's maxillary retractor

Fig. 18.7 Bite blocks

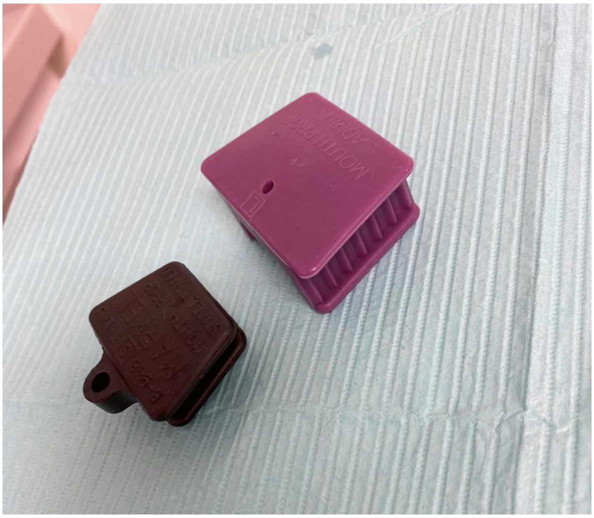


Fig. 18.8 Molt #9 periosteal elevator



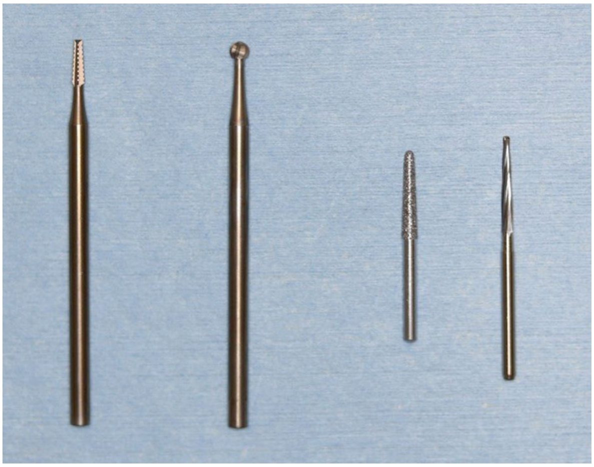


Fig. 18.9 Surgical carbide burs utilized in the extraction of mandibular third molars include fissure burs and round burs

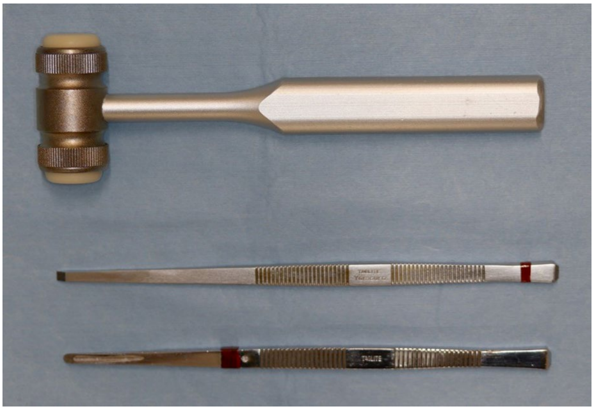


Fig. 18.10 Mallet and osteotomes

Mallet, Osteotome, and Chisel

The osteotome or bone chisel is used in conjunction with a mallet, to remove bone that is covering an impacted tooth and to create an insertion site for seating the elevators. It can also be used to divide the dentin. There are various types, including a round chisel, square chisel, and flat chisel. Due to advances in handpieces, the frequency of using this instrument has decreased in recent years (Fig. 18.10).

Elevators

Straight Elevators Straight elevators come in various dimensions, with a rounded end or flat end (Coupland's chisel elevator), with concave and convex sides. They are utilized in third molar extractions by wedging and luxating teeth, severing the periodontal ligament, expanding the socket, and levering between the tooth and bone to allow for elevation of tooth. The offset straight elevator has an angle in the shank allowing for better access particularly to posterior teeth (Fig. 18.11).

Apexo Elevators Also known as root tip picks, these are angular-paired or straight elevators containing thin blades with concave and convex sides and are utilized to access and remove fractured, residual root tips or foreign objects inside tooth sockets (Fig. 18.12).



Fig. 18.11 Straight elevators

Fig. 18.12 Apexo elevators

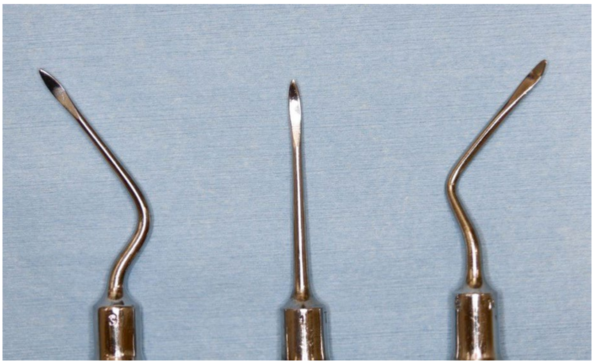




Fig. 18.13 Crane Pick elevator

Crane Pick Elevators This is an elevator with a sharp, 45-degree angled tip that makes it ideal for elevating root tips (Fig. 18.13).

Cryer Elevators These are paired elevators containing a triangular shaped blade with concave and convex sides, designed to remove root pieces of mandibular molars when either the mesial or distal root has been removed. The concave side should hug the root piece or interproximal bone to be removed, while the operator rotates the instrument in a wheel-and-axis manner.

Forceps

The universal mandibular forceps can be used to extract vertically erupted mandibular third molars or after adequate elevation of partially or fully impacted third molars. For fully erupted third molars, Cowhorn forceps, aptly named after the shape of its beaks, can be seated in the root furcation, when possible, in order to lift and extract the tooth (Fig. 18.14).



Fig. 18.14 Universal mandibular forceps



Fig 18.15 Rongeurs

Rongeurs

This instrument can be side cutting or side cutting and end cutting. They often are used in conjunction with a bone file to remove sharp edges of alveolar bone after tooth extraction that may impede proper healing (Fig. 18.15).



Fig. 18.16 Bone files

Bone File

Bone files contain a cross-hatched surface with one-directional cutting edges that allows bone to be smoothened when applied in a pulling action. This is often used in conjunction with rongeurs to remove sharp edges of bone to ensure proper healing after tooth extraction (Fig. 18.16).

Dental Curettes

This instrument comes in varying sizes of spoon-shaped ends with an angled shank, used to remove infectious tissue or granulomas, follicles, cysts, and foreign substances in tooth extraction sockets (Fig. 18.17).

Irrigation Syringe

A 10-cc or larger syringe with sterile saline is used to copiously irrigate loose pieces of bone fragments, granulation tissue, and foreign substances in extraction sites in order to allow for proper healing (Fig. 18.18).

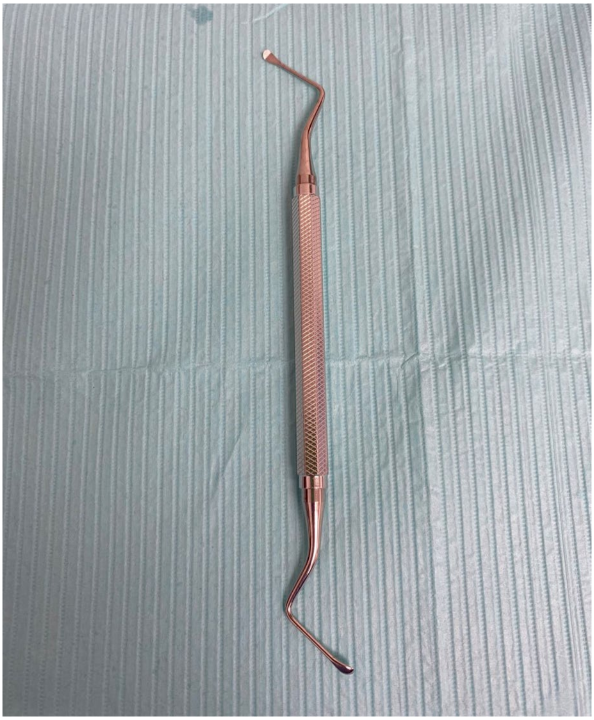


Fig. 18.17 Dental curettes



Fig. 18.18 Irrigation syringe

Suture Scissors

For cutting suture to desired length or for removal of sutures. The tip may be straight or curved based on operator preference. A length of about 17 cm is easy to use (Fig. 18.19).



Fig. 18.19 Suture scissors

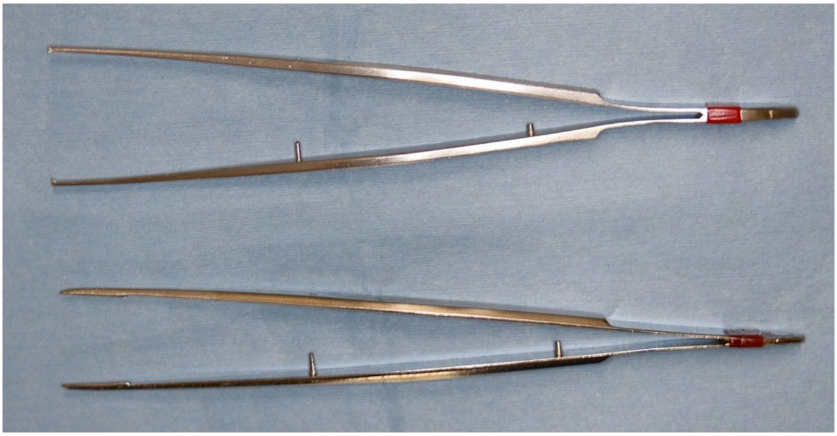


Fig. 18.20 Tissue holding forceps

Tissue Holding Forceps

Non-toothed tissue forceps are generally utilized to handle and manipulate mucosal tissue when making incisions or suturing. They are designed to minimize damage to soft tissues while providing grip, such that tissue can be manipulated in order to be more amenable to perpendicular entry of the suture needle (Fig. 18.20).

Needle Holder

The needle holder or needle driver is a surgical instrument used for suturing by holding the suture needle with attached thread. While there are many different designs, such as the Mayo-Hegar and Mathieu needle holders, among others, the Hegar needle holder is most used in the oral cavity. The beaks contain a cross-hatched pattern to help grip the suture needle securely without damaging it (Fig. 18.21).

Sutures and Needles

Needle Suture needles aid in passing of thread through mucosal tissues. While there are a myriad of suturing needles, the suture needles used to approximate mucosal tissues are usually curved, three-eighth or one-half circle, reverse-cutting needles (Figs. 18.22, 18.23, 18.24 and 18.25, Tables 18.1, 18.2 and 18.3).

Sutures Oral mucosal tissues are typically reapproximated with size 3-0 chromic gut or fast gut absorbable sutures. Alternatives, depending on operator preference and patient presentation, may be considered based on suture properties. There are many sizes and types of sutures, and they are selected according to the site and purpose of suturing. The shape of the thread is a monofilament or braided (Table 18.4).

Thread materials can be broadly divided into absorbent and non-absorbent.



Fig. 18.21 Needle holder

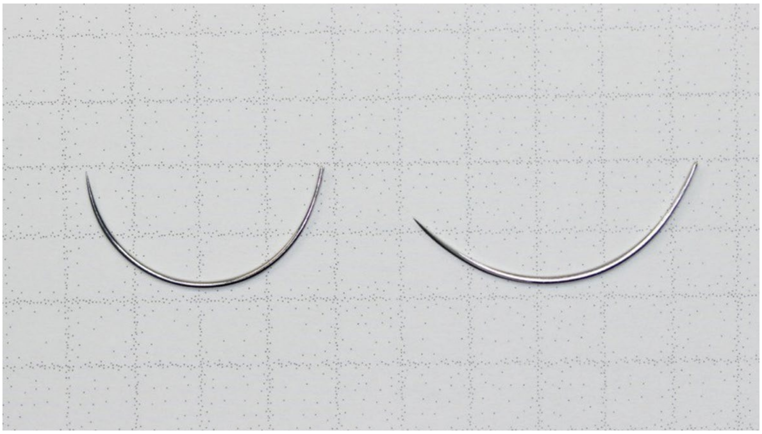


Fig. 18.22 Needles-1

Fig. 18.23 Needles-2

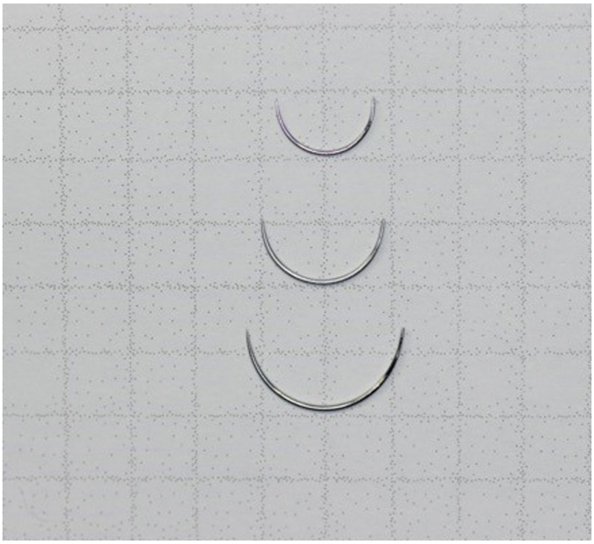


Fig. 18.24 Needles-3



Fig. 18.25 Straight needle

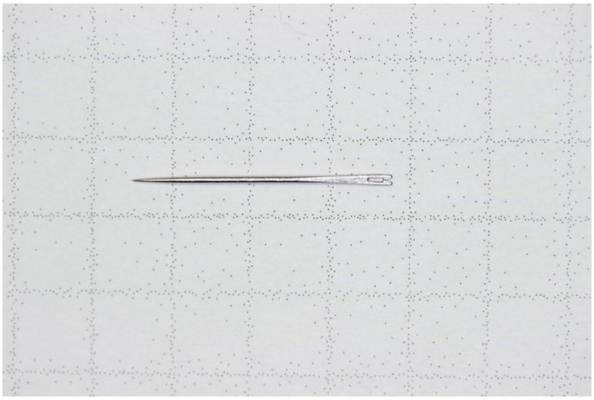


Table 18.1 Straight and curved needles

Straight	Used for interdental papilla
Curved	Used for normal tissue suturing

Table 18.2 Shape of needle tip

	Round needle	Triangular needle
Tissue damage	Less	More
Tissue penetration	Fine	Good
Tissue damage	Less	More
Used for	Soft tissue except skin	Skin

Table 18.3 Curvature of needles

Strong curvature (1/2, 180°)	Used for suturing narrow area
Weak curvature (3/8, 135°)	Used for suturing wider area

Table 18.4 Features of monofilament and braid

	Monofilament	Braid
Advantages	Good tissue passage Hard to get dirty	Hard to cut Good operability Nodules are hard to loosen
Disadvantages	Relatively difficult to operate Nodules are easy to loosen	Not good tissue passage Easy to get dirty

Non-absorbent

This type of suture is not absorbed by the body and thus has long-term tensile strength.

Silk thread is supple, has excellent operability, is inexpensive, and has little tissue reaction.

Nylon thread has good tissue passage and tissue reaction is very low.

Absorbency

It has a tensile strength that maintains the wound for a certain period of time and is then absorbed by hydrolysis. The tensile strength and absorption time vary depending on the type.

PGA glycolic acid and polyester lactate are high-molecular-weight compounds that have almost no tissue reaction and are hydrolysed in vivo. They pass through the tissues easily, are supple, and easy to tie.

Inferior Alveolar Nerve Blockade and Infiltration Anaesthesia Techniques for Mandibular Third Molar Extraction

19

Tsuyoshi Tanaka and Joe Iwanaga

Introduction

Effective and safe pain management during a third molar extraction is crucial to completing the treatment successfully and getting patient satisfaction. The inferior alveolar nerve block (IANB) and local infiltration anaesthesia are the most common injection techniques used for the extraction of mandibular third molars and other procedures performed on the lower molars. However, reports of the success rate of IANB vary significantly among studies, ranging from 23%, by using 2.2 ml of 2% lidocaine with 1:100,000 epinephrine for treating irreversible pulpitis on mandibular premolars or molars (Claffey et al. 2004), to 92% by using 1.8 ml of 2% lidocaine with 1:100,000 epinephrine for anaesthetizing healthy mandibular second

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molars (Hannan et al. 1999). This relatively high failure rate of IANB has been related to numerous factors, including operational errors, anatomical variations, infection, inflammation, pathological conditions, and psychological aspects such as fear, stress, and anxiety. According to Al Hindi et al. (2016), poor technique and anatomical variations are the primary cause of IANB failure. Therefore, in this chapter, we review the proper techniques for delivering inferior alveolar nerve anaesthesia for mandibular third molar extraction, emphasizing the importance of knowing the anatomy of the region to be anesthetized and the properties of local anaesthetic drugs used in dentistry.

Understand the Gross Anatomy of the Pterygomandibular Space

Knowledge of the gross anatomy of the pterygomandibular space is crucial for achieving effective IANB. The pterygomandibular space is triangular in shape and is surrounded laterally by the mandibular ramus, medially and inferiorly by the medial pterygoid muscle. The buccinator, superior pharyngeal constrictor, and pterygomandibular raphe are found anteriorly, while the parotid gland is located posteriorly. The pterygomandibular space contains the inferior alveolar nerve (IAN), artery and vein, pterygoid venous plexus, the lingual nerve, the nerve to the mylohyoid muscle, and the sphenomandibular ligament (Fig. 19.1). The IAN is protected anteriorly by the lingula which is a triangular-shaped projection at the medial side of the mandible and is what the sphenomandibular ligament is attached to. The sphenomandibular ligament may impede anaesthetic solution diffusion. If the needle is inserted medial to the sphenomandibular ligament, the IAN may not be sufficiently anaesthetized, and the needle may traumatize the medial pterygoid muscle

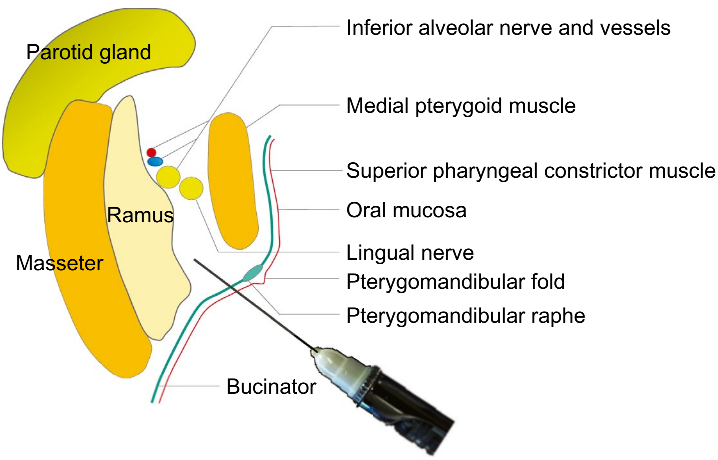


Fig. 19.1 Axial view of the right pterygomandibular space at the level of mandibular foramen

which can cause trismus after an IANB. Compared to the IAN, the lingual nerve is not covered by a bony or dense ligament protection. Thus, anaesthetic solutions work better on the lingual nerve than on the IAN, and the lingual nerve can be injured more frequently than the IAN (Pippi et al. 2017; Pogrel et al. 2003).

It is important to highlight that the IANB can anaesthetize the neurovascular bundle in the pterygomandibular space, and this can cause localized complications of the middle ear, eye, and face. On some patients, the auriculotemporal nerve may have branches which connect to the IAN or facial nerve. If the auriculotemporal nerve arises more inferiorly and close to the IAN, this can result in numbness around the auricle following an IANB. Therefore, it is advisable to inform the patient that, in certain cases, the IANB may also anaesthetize the ear or the temple in addition to the oral cavity.

Steps for a Standard IANB Technique

The following steps will guide clinicians in performing a proper IANB:

Step 1: Locate the main intraoral anatomical landmarks.

Identification of the following three anatomical landmarks is crucial for a successful IANB:

1. External oblique ridge
2. Coronoid notch
3. Pterygomandibular fold

Step 1-1: Palpate the external oblique ridge and find the coronoid notch.

The first step for an IANB is to find the external oblique ridge, an easily identifiable bony landmark. Initially, palpate the external oblique ridge until the concavity is reached, i.e. the coronoid notch. Move your thumb or finger medially until you palpate the internal oblique ridge. It is important to realize that the identification of this anatomical landmark can be difficult in patients with obesity, atrophed mandibles, and a sensitive gag reflex. Therefore, the recognition of the internal oblique ridge is helpful but is not a mandatory step.

Step 1-2: Find the pterygomandibular fold.

The pterygomandibular fold is formed on the surface of the pterygomandibular raphe which is the junction of the buccinator muscle and the superior pharyngeal constrictor muscle.

Step 2: Dry the *area of needle insertion and apply 20% topical benzocaine for 1–2 min.*

Step 3: Ask the *patient to open their mouth fully.*

The needle insertion point is the pterygomandibular depression which is located just lateral to the pterygomandibular fold (Fig. 19.2). The pterygomandibular depression could be more visible when the patient fully opens their mouth so that the needle insertion should be easier. In case the patient cannot widely open the mouth, closed-mouth block anaesthesia technique is recommended. The syringe barrel is placed at the contralateral canine and premolars to have best access and precise angulation. Degree of ramal flaring varies among individuals (Fig. 19.3). If

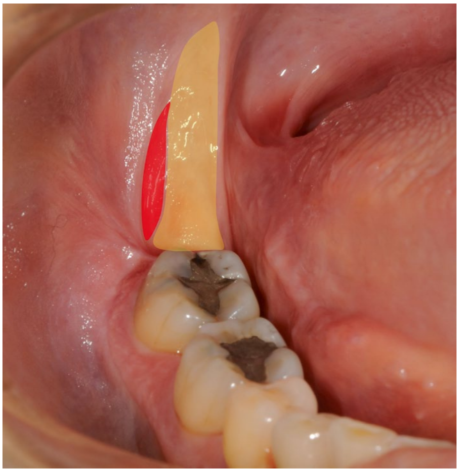


Fig. 19.2 Pterygomandibular fold (yellow) and coronoid notch (red)

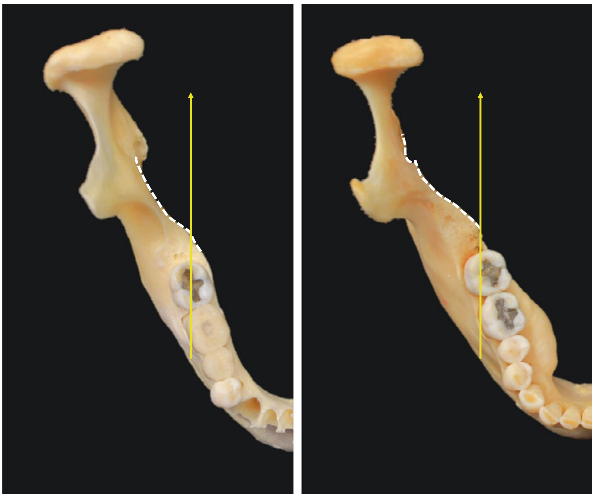


Fig. 19.3 The degree of ramal flaring varies

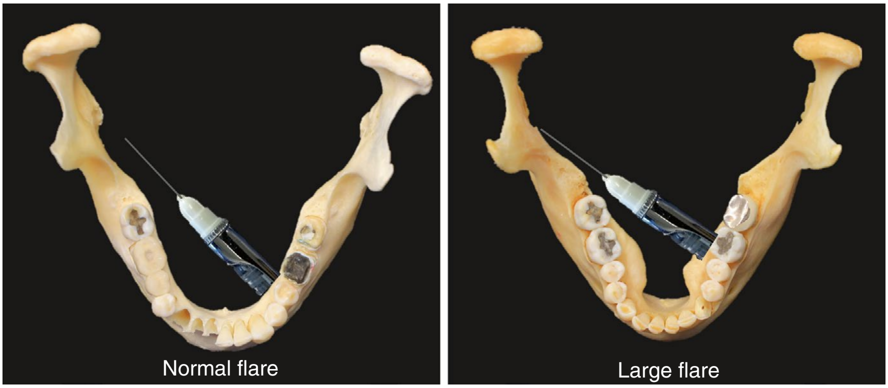


Fig. 19.4 The needle should be angled further posteriorly if the patient has a large flaring angle

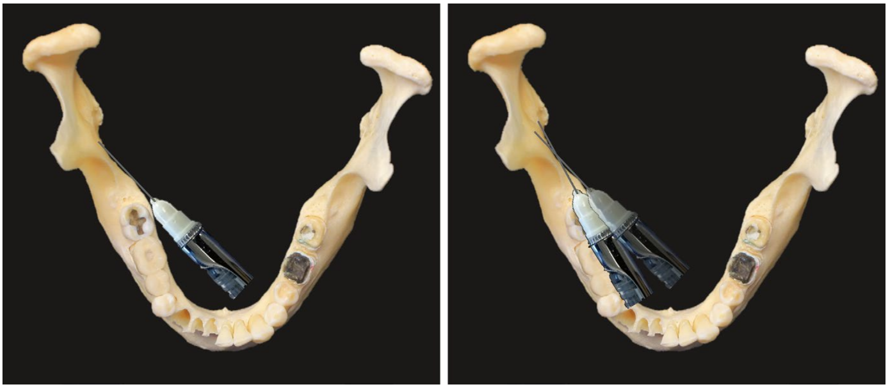


Fig. 19.5 For the best access and angulation, the syringe barrel is positioned at the contralateral canine and premolars. The needle is advanced until the medial side of the mandibular ramus is touched. To reach the lingula of the mandible/mandibular foramen (inferior alveolar foramen), the syringe is moved to the medial side, and the needle is advanced while maintaining continuous bone contact

the patient has a wide flaring angle, syringe has to be positioned more posteriorly (Fig. 19.4). The needle is then advanced until the medial surface of the mandibular ramus is contacted. To reach the lingula of the mandible/mandibular foramen (inferior alveolar foramen) area, the syringe is moved medially, and the needle is advanced while maintaining continuous bone contact (Fig. 19.5). It is recommended not to strike the bone too vigourlessly in order to avoid damaging the needle tip. Once the needle tip is damaged and barbed, it can cause tissue trauma while advancing the needle. Anaesthetic drugs should be injected as close to the lingula (i.e. adjacent to the mandibular foramen). The distance from the anterior border of ramus to the lingula of the mandible is about 20.6 ± 3.5 mm. The height of the lingula and its location in relation to the occlusal plane of the mandibular molars are approximately 8.2 ± 2.3 mm (Jansisyanont et al. 2009). Therefore, a 32-mm-long needle is

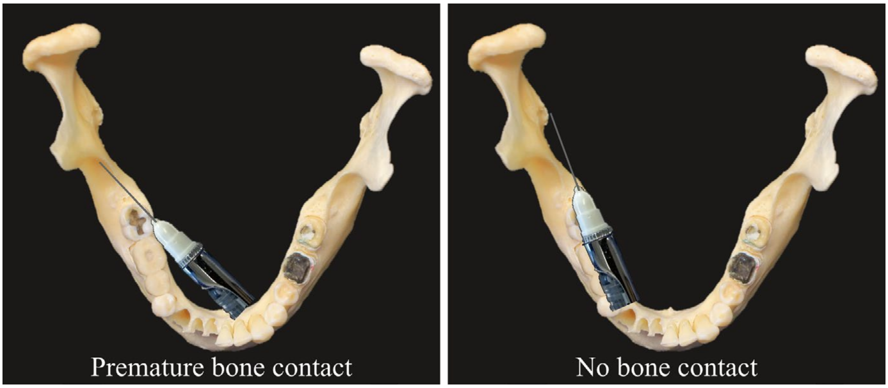


Fig. 19.6 Premature bone contact – insertion point may be too laterally or anteriorly.No bone contact – insertion point may be too medially or posteriorly

recommended for an IANB with insertion depths from 20 to 25 mm and heights of 10 mm above the occlusal plane. If the bone is touched soon after the needle is inserted, it may be too far anteriorly on the ramus. In this case, pull the needle back slightly without taking it out of the tissue completely, and change the syringe angulation slowly towards the midline over the canine, and insert the needle again until reaching 20–25 mm in depth. If the bone is not felt during needle insertion, it may be inserted too posteriorly. In this case, slightly pull the needle back slightly without taking it out of the tissue completely, and change the needle angle towards the molars (Fig. 19.6). Then, advance the needle until the bone is felt.

Step 4: Aspirate.

Negative aspiration should be confirmed before the injection of the local anaesthetic solution. A dental aspirating syringe is strongly recommended for this purpose. Even experienced oral and maxillofacial surgeons have reported a frequency of intravascular needle entrance during an IANB injection of 15.3% (Taghavi Zenouz et al. 2008). In the pterygomandibular space, the vessels that are most often cited as being damaged are the inferior alveolar vessels; however, these vessels enter the mandibular foramen and are protected by the lingula. Actually, the pterygoid venous plexus is the structure most at risk. If blood is aspirated, remove the needle, change both the needle and the cartridge, and repeat the steps for IANB.

Step 5: Deliver the anaesthetic *drug.*

Common local anaesthetic drugs used in dentistry include lidocaine, articaine, mepivacaine, bupivacaine, and prilocaine. For IANB for third molar extraction, 2% lidocaine with 1:100,000 epinephrine or articaine 4% with 1:100,000 epinephrine is

typically used. 4% articaine with 1:100,000 epinephrine can achieve better success rates of anaesthesia and longer durations than 2% lidocaine with 1:100,000 epinephrine. However, a higher incidence of paraesthesia has been reported following the use of 4% articaine compared to other anaesthetics (Haas and Lennon 1995). Lidocaine is thus suggested for nerve block due to the lower risk of complications. Slow anaesthetic drug release is recommended, e.g. ~ 60 s for 1.8 ml of anaesthetic solution.

Step 6: Withdraw the *syringe.*

The needle/syringe must be removed from the mouth slowly to avoid any complications by the needle tip.

Step 7: Verify successful anaesthesia.

The symptoms of numbness/tingling and loss of sensation begin within 3–5 min after an IANB. IANB takes 15 min to achieve complete effects (Vreeland et al. 1989). Checking lip and tongue numbness is helpful for confirming the success of an IANB. However, it does not always ensure pulpal anaesthesia due to anatomical variations.

Step 8: Supplement *local anaesthetic and anaesthetize the buccal mucosa.*

Since the success rate of IANB is reported to be around 80%, supplemental anaesthesia through local infiltrations has been suggested for patients who respond less positively to IANB. However, it is important to wait for signs of lip/tongue numbness before completing the local infiltration. More importantly, an IANB does not anaesthetize the facial soft tissues over the molar area (Fig. 19.7). Thus, supplemental local infiltration is required for molar extractions. A network meta-analysis by Camps-Font et al. (2020) found that 4% articaine yielded a significantly higher success rate for IANB than 2% lidocaine, 0.5% bupivacaine, and 1% ropivacaine for impacted mandibular third molar extraction. According to Kanaa et al. (2009), articaine buccal infiltration in combination with lidocaine IANB infiltration was more effective than lidocaine IANB alone. One can find dental books reporting that an IANB requires "long buccal nerve block" by injecting lateral to the third molar. Such books often present a figure showing the main trunk of the buccal nerve running on the buccal shelf of the mandible. However, anatomists do not believe that the course of the buccal nerve is on the buccal shelf, but dentists do. Dental textbooks have often shown incorrect anatomy for the buccal nerve, and therefore, this has become "common knowledge in dentistry". To correct this, Iwanaga and Tubbs (2019) performed a study in cadavers and demonstrated that the main trunk of the buccal nerve travels much higher than the buccal shelf area. Therefore, the current "long buccal nerve block" injection site should be referred to as an infiltration

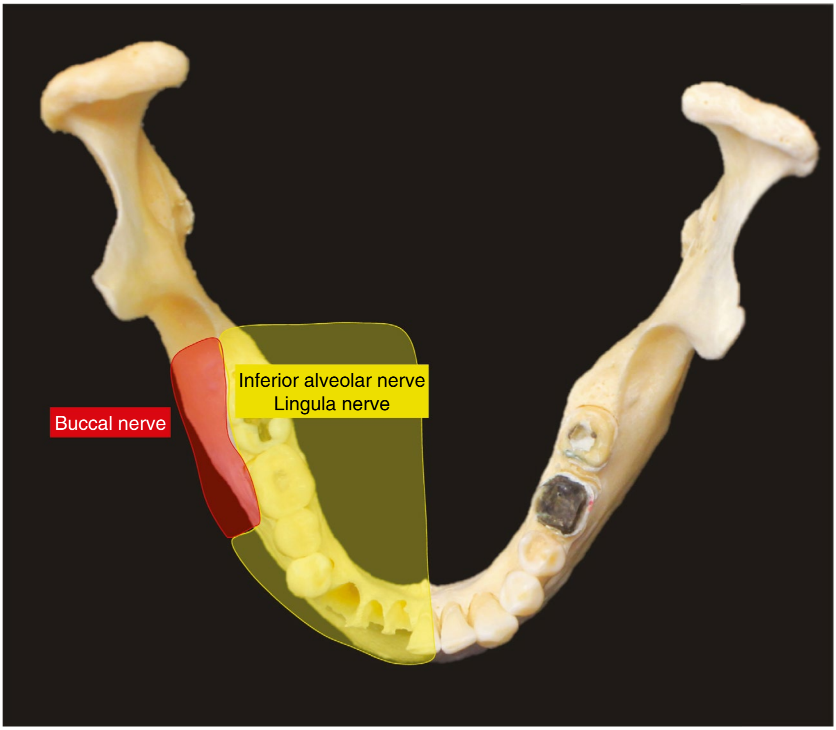


Fig. 19.7 Distribution of anaesthesia after IANB

technique of the buccal nerve branch rather than a blockade technique, as it does not reach the main trunk of the buccal nerve.

Step 9: Perform *a second IANB, if necessary.*

A recent systematic review with meta-analysis (Nagendrababu et al. 2021) revealed that 3.6 mL of anaesthetic solution yields a higher IANB success rate than a 1.8 mL solution. This might be due to a greater volume of anaesthetic solution filling the pterygomandibular space and, consequently, greater IAN exposure to the anaesthetic solution. Additionally, administering two separate injections increases the chance that the anaesthetic solution accumulates around the mandibular foramen. Therefore, if the first IANB attempt is unsuccessful, insertion point height, depth, and syringe angulation should be modified for the second attempt.

A clinical study evaluating CBCT demonstrated that the mandibular foramen is located, on average, 9.83 mm above the occlusal plane (Blacher et al. 2016). Although the mandibular foramen position varied considerably from the minimum reference value of 6 mm, it did not differ significantly from the highest reference value of 10 mm (Fig. 19.8). Thus, the needle insertion point in a second

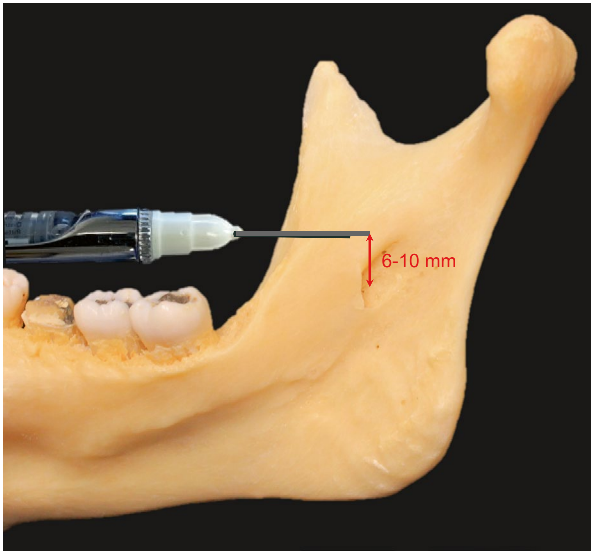


Fig. 19.8 The mandibular foramen is located significantly higher than 6 mm above the mandibular occlusal plane, but not higher than 10 mm

attempt of an IANB should be higher than the first attempt. Gravity may help the diffusion of anaesthetic solution in the inferior direction to reach the mandibular foramen.

Anatomical Variations That May Increase the Risk of IANB Failure

For a complete IANB, the anaesthetic solution must be delivered close to the mandibular foramen where the inferior alveolar nerve enters the mandibular ramus. However, scientific evidence has showed that the position of the mandibular foramen varies considerably among individuals. These anatomical variations may impact the success rate of an IANB. It is crucial to identify the anatomical differences that might result in IANB failure in order to increase success rates. Performing IANB techniques poorly can be the main reason of failure if a patient reports loss of sensation around the injection site but not on the ipsilateral lip or chin. However, anatomical variations should be taken into account if the patient reports numbness of the lips and chin but not on the teeth. Studies have described anatomical variations that may reduce the success rate of an IANB, including the presence of a retromolar foramen, bifid mandibular nerve, prognathism, retrognathism, and ramal flaring.

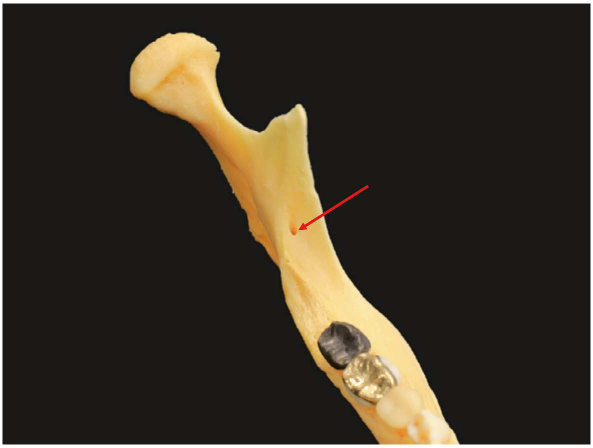


Fig. 19.9 Retromolar foramen (arrow)

Retromolar Foramen

Previous clinical studies using CBCT demonstrated that the prevalence of a retromolar foramen (Fig. 19.9) was 26% (Kikuta et al. 2018). It has been shown that the presence of retromolar canal and foramen can be one of the main causes for failure of a standard IANB. The retromolar canal and foramen possess neuromuscular elements that provide additional nerve supply. Consequently, the IANB only is not able to provide a complete numb of the mandibular molar area, especially the third molars. Unfortunately, simply repeating IANB does not assist in these cases. Supplemental local infiltration is necessary to improve anaesthetic success.

Bifid Mandibular Canals

Studies assessing CBCT images show that the prevalence of a bifid mandibular canal varies from 10.2% to 65% (Muinelo-Lorenzo et al. 2014, Naitoh et al. 2009, Zhou et al. 2020). In 1983, Grover and London reported that a bifid mandibular canal does not relate to failure of an IANB. Later, Sanchis et al. (2003) revealed that mandibular anaesthesia may be more difficult to obtain by means of the traditional IANB when bifid mandibular canals are present. This discrepancy between studies may be explained by the fact that some canals contain blood vessels and nerves, while other canals have blood vessels only. An IANB can be more difficult to achieve if the two separate bifid mandibular canals contain an inferior alveolar nerve. In this case, alternative anaesthesia techniques will be necessary (i.e. periodontal ligament injection, intraosseous anaesthesia, Gow-Gates mandibular nerve block, and Vazirani-Akinosi nerve block).

Mandibular Prognathism and Retrognathism

Another anatomical feature that can affect the success of IANB is mandibular prognathism. It is more challenging for the operator to insert the needle at the proper height in prognathic mandibles because the mandibular foramen is typically located higher than the coronoid notch. Thus, it is recommended to insert the needle at a higher position in patients with prognathic mandible.

According to You et al. (2015), the rates of failure of IANB for a retrognathic mandible (14.5%) were substantially greater than those in normal (7.3%) and prognathic (9.5%) mandibles. This is explained by the fact that the mandibular foramen is located higher in retrognathic patients. As a result, the anaesthetic solution is injected below the mandibular foramen when using a conventional IANB technique in patients with retrognathism, leading to significant failure rates. In addition, inadequate mouth opening brought on by short condyle length is thought to be another reason for an unsuccessful IANB in retrognathic patients. Finally, anaesthetic solution can be administered above the mandibular foramen because the mandibular foramen is located lower in patients with prognathic mandibles. According to Keros et al. (2001), individuals who underwent successful IANB had a lower mandibular foramen. Anaesthetic solutions should thus be administered higher when treating individuals with retrognathic mandibles.

Ramal Flaring

The degree of ramal flaring varies among patients (Fig. 19.4). Thus, if the first IANB attempt is not successful, the syringe angulation should be changed for the second attempt along with ramal flaring. Blacher et al. (2016) indicated that the mental foramen is around 42°–45° from the contralateral premolar. Therefore, positioning the syringe barrel above the opposing premolar contact region and refining this angle would provide a predictable and repeatable method for achieving the proper angulation for delivering an IANB.

Complications

In general, complications related to IANB technique comprise five types: injuries to nerves, injuries to blood vessels, injections into the parotid gland, trauma to muscles, and systemic reactions. Other complications include intravascular injection, anaesthetic drug overdose, allergic and anaphylactic reactions, facial nerve paralysis, numbness of the ear, hematoma, trismus, blanching of the skin, soft tissue necrosis, spread of infection, soft tissue trauma, ocular complications (transient loss of vision, diplopia), and needle breakage. The most common complications related to IANB are facial paralysis, haematoma, and trismus (Al Hindi et al. 2016).

Conclusion

This chapter covers the general anatomy of the pterygomandibular area, the basic steps for an IANB technique, anatomical variations, and complications associated with an IANB. Understanding the anatomical structures around the IAN is critical for providing a safe and effective IANB.

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Incisions for Mandibular Third Molar Extraction

20

Shogo Kikuta, Joe Iwanaga, and Jingo Kusukawa

Introduction

A flap design for the mandibular third molar extraction is important for a successful procedure. Inappropriate flap could result in unfavourable outcomes. By performing sufficient simulation before mandibular third molar removal, complications can be avoided and widely applied. Although there are few variations in flap design for mandibular third molar extraction (Baqain et al. 2012; Berwick 1966; Chen et al. 2017; Kirtiloğlu et al. 2007; Menziletoglu et al. 2020; Nageshwar 2002; Rai and Rai 2017; Stephens et al. 1983; Suarez-Cunqueiro et al. 2003; Szmyd 1971; Yolcu and Acar 2015; Zhu et al. 2020), it is possible to perform mandibular third molar

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extraction faster and safer by making an appropriate incision, and it can be modified on a case by case basis.

Flap Design and Blood Flow

Generally, although blood flow is cut off on the incision line, the incision at the free edge or elevation of the flap may induce poor circulation or necrosis. Especially, as the triangular flap design for mandibular third molar extraction is a random pattern flap without major feeding vessels, the base of the flap should not be too narrow. The ratio of the base to the flap length is up to 1:2 as the area where the flap can be safely lifted on the principle of a random pattern flap (Fig. 20.1).

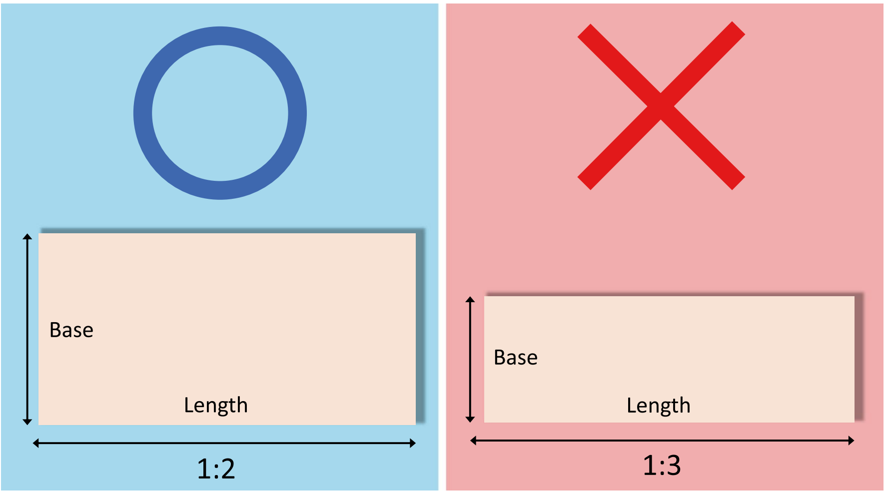


Fig. 20.1 Random pattern flap. The ratio of the base to the flap length is up to 1:2

Triangular Flap

Most of the incisions for mandibular third molar extraction are the triangular flap or its modified technique. The advantages of the triangular flap are (1) sufficient blood supply to the apex of the triangle from its wide base and (2) ease of modifying the incision such as adding the periosteal releasing incision, vertical incision, or extending the incision. By contrast, the triangular flap could induce inflammation in the muscles of mastication as the vertical incision induces muscle irritation with haematoma and oedema (Baqain et al. 2012). Moreover, Zhu et al. suggested that the vertical incision to the buccal gingiva might cause the release of local inflammatory mediators, resulting in more postoperative pain (Zhu et al. 2020). The configuration of the triangular flap is formed by elevating the flap towards the base from the apex of the triangle composed by connecting the line extending obliquely outwards from the distal to the mandibular second molar and the line extending from there to the buccal side of the second molar (Fig. 20.2). However, the final flap design does not necessarily make a “triangle” because of the presence of the second mandibular molar and other anatomical limitations.

The triangle flap for the mandibular third molar extraction is classified into two types, i.e., the buccal based triangular flap and the lingual based triangular flap depending on the position of the base (Figs. 20.3 and 20.4) (Baqain et al. 2012; Chen et al. 2017; Menziletoglu et al. 2020; Rai and Rai 2017; Yolcu and Acar 2015;

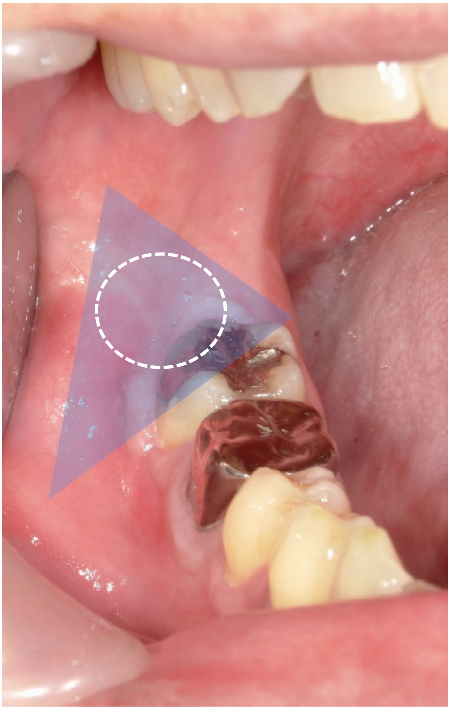


Fig. 20.2 Theory of the triangular flap. Include the surgical field in the virtual triangle. Blue triangle, virtual triangle; white dotted line, third molar

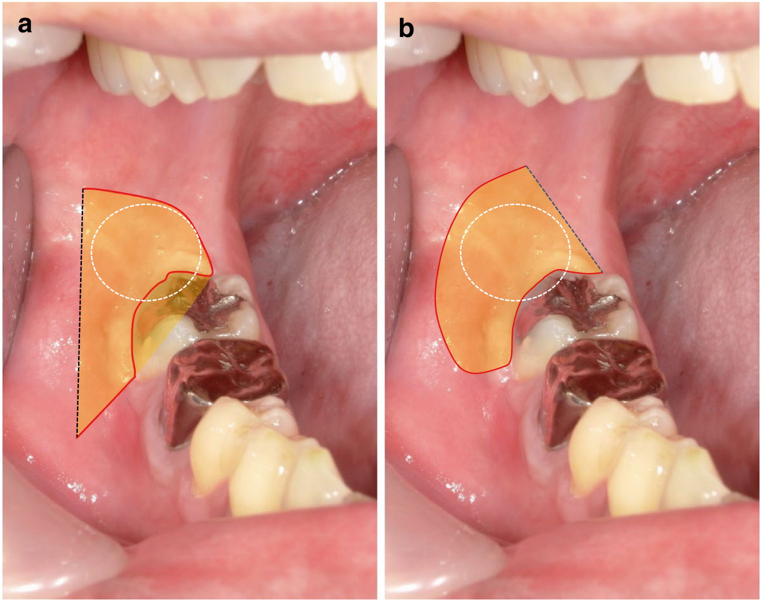


Fig. 20.3 (**a**) Buccal based triangular flap, (**b**) Lingual based triangular flap. Red solid line, incision line; white dotted line, third molar; black dotted line, base of the flap

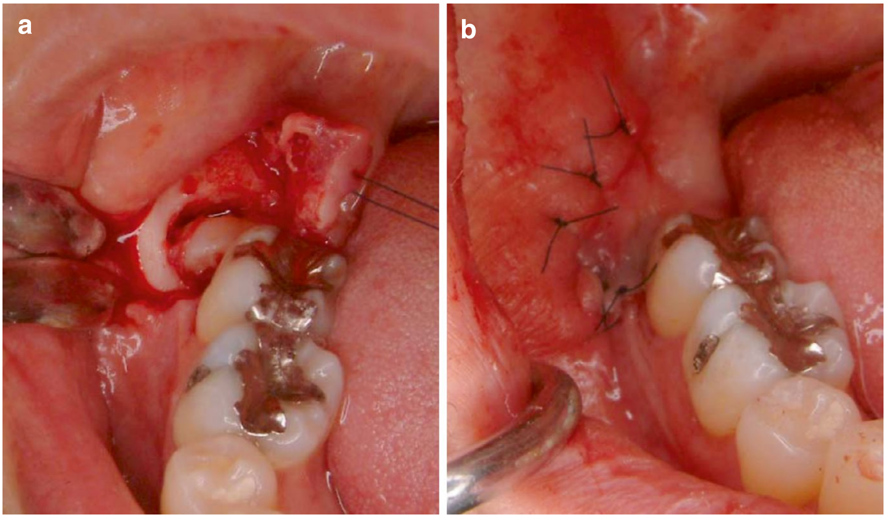


Fig. 20.4 Lingual-based triangular flap. (**a**) Following the mucoperiosteal flap elevation, (**b**) After suture

Zhu et al. 2020). In general, the buccal-based triangular flap is used in the vast majority of cases.

The Buccal-Based Triangular Flap and Principles of the Incision Line

There are several basic principles for a safe and effective incision for the mandibular third molar extraction.

Principle 1: The surgical field included within the incision line

Excessive buccal traction of the flap can result in mucosal dehiscence or damage. In most of these cases, surgeons design the initial flap too small to extract the tooth as they believe it can minimize the surgical invasion. Incisions that are too small and the surgical field can lead to various anatomical issues.

Principle 2: Incision is anatomically safe

The most important anatomical structure to note in an incision for mandibular third molar extraction is the lingual nerve. When the origin of the incision along the external oblique ridge from the distal part of the mandibular second molar is too close to the floor, it can damage the lingual nerve. Behnia et al. showed a two-dimensional illustration for the abnormal pathway of the lingual nerve (Behnia et al. 2000). On the other hand, these illustrations would cause the surgeon to misunderstand that the abnormal course of the lingual nerve runs on the retromolar pad. Iwanaga et al. demonstrated that the retromolar pad is the overlying mucosa of the retromolar gland with no lingual nerve running across the retromolar gland (Iwanaga et al. 2020a). They recommended using the retromolar pad as a landmark for avoiding iatrogenic lingual nerve injury (Iwanaga et al. 2020a). With this principle, surgeons should directly palpate the underlining bone before making the incision.

Cone-beam computed tomography (CBCT) is a useful modality in mandibular third molar extraction as surgeons can confirm the anatomical variants such as the retromolar foramen and other accessory foramina of the mandible. Even if a patient has an accessory foramen, this may be negligible, especially if it is small (Iwanaga et al. 2019). Kikuta et al. reported postoperative hypoesthesia of the buccal mucosa after mandibular third molar extraction due to iatrogenic injury of a retromolar foramen that was 2.3mm in diameter (Kikuta et al. 2018). In the case of a large retromolar foramen and other accessory foramina, surgeons should modify the incision line to avoid injury or ligate the neurovascular bundle (Fig. 20.5). Also, the presence of these anatomical variants and their complications need to be conveyed to the patient.

Principle 3: Incision line perpendicular to the tangent line

An incision line perpendicular to the tangent line to the cervical region of the tooth is essential for making tight contact on each wound surface and provide

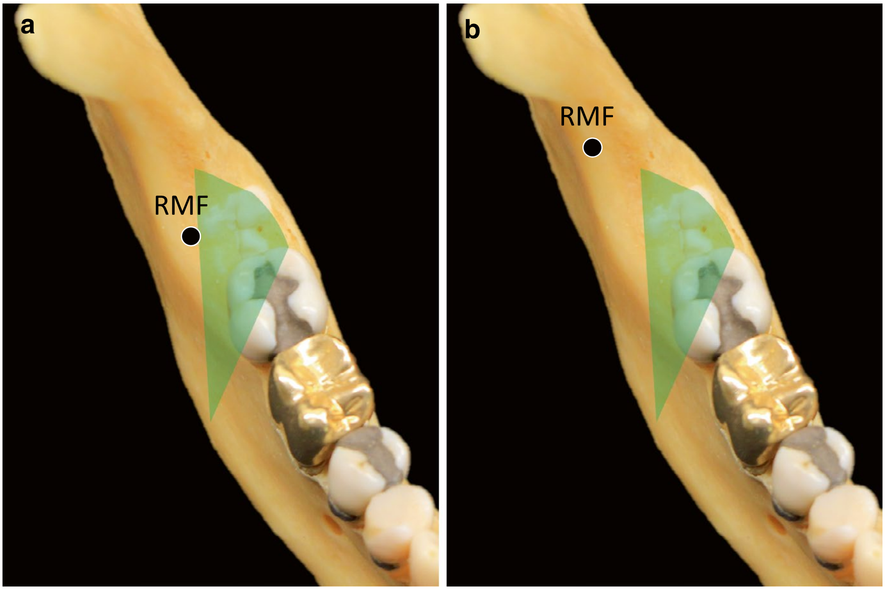


Fig. 20.5 Retromolar foramen (RMF, black dots) and triangular flap (green area). (**a**) When the retromolar foramen is close to the flap, there is a high risk of injury, (**b**) When the retromolar foramen is far from the flap, it is less likely to get injured

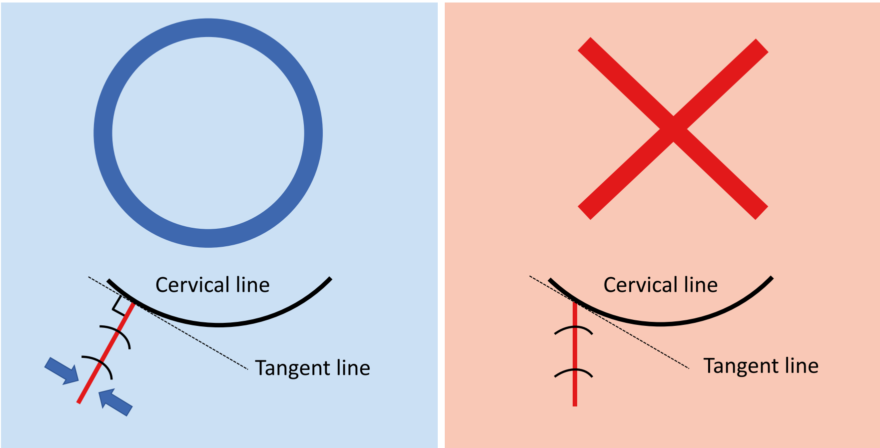


Fig. 20.6 Setting up the incision line perpendicular to the tangent line to the cervical region of the tooth. Deviations from this principle may result in difficulty in suturing and insufficient blood flow at the tip of the flap

adequate blood flow to the apex of the flap (Fig. 20.6). Therefore, the origin of the vertical incision is set so as to deviate slightly from the outline of the triangle. Even though there may not be a significant difference in postoperative healing in the long term, it is a principle we should know when performing oral surgery.

Principle 4: The incision always needs to be modified by using a curved incision to provide enough width, length, and blood supply

The outline of the triangular shape should be used just as a guide, and minor adjustments should be made, when necessary, although the principles 1 to 3 need to be kept in mind. The surgical field made by the incision line should fall into place inside the triangle.

Lingual-Based Triangular Flap

In 1966, Berwick firstly advocated a lingual-based triangular flap which has a base at the distolingual aspect of the mandibular second molar (Berwick 1966). Recently, several researchers have compared and reported the lingual based triangular flap to the routinely used buccal-based triangular flap for postoperative complications of mandibular third molar extraction (Menziletoglu et al. 2020; Rai and Rai 2017; Yolcu and Acar 2015). The advantage of the lingual-based triangular flap is that the incision line is not placed on the bony defect made by mandibular third molar extraction so that the wound is less likely to dehisce compared to the buccal-based triangular flap. The lingual-based triangular flap leads to primary healing, while most of the buccal-based triangular flap leads to secondary healing as the wound is easy to dehisce (Rai and Rai 2017). On the other hand, to maintain the blood flow of this flap, it is important to have a wide base so that the flap apex does not become too thin, which is more like a U shape rather than a triangle (Fig. 20.4). Moreover, the facial artery or its branch can be damaged if the surgical invasion reaches the facial soft tissues (Iwanaga et al. 2020b; Takeshita et al. 2021).

Pros and Cons of the Vertical Incision

A few studies had evaluated the pros and cons and postoperative complications of vertical releasing incision for mandibular third molar extraction (Baqain et al. 2012; Chen et al. 2017; Naruse 2021; Zhu et al. 2020). When mandibular third molar extraction is positioned relative to the superficial position, e.g. Pell and Gregory Position A or B, envelope flaps can be used without the vertical incision resulting in a reduction of surgical time and postoperative complication, e.g. pain and trismus (Naruse 2021; Zhu et al. 2020). In contrast, Baqain et al. reported that postoperative swelling and reduction in mouth opening after using the triangular flap improved earlier than adding the vertical incision (Baqain et al. 2012). The triangular flap has the advantage of a wide surgical field and easier flap peeling, while the envelope

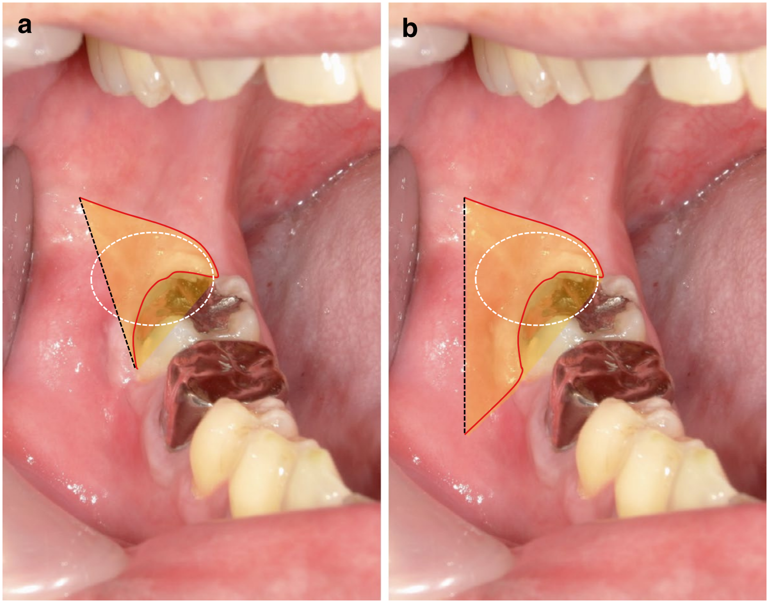


Fig. 20.7 Difference of triangular flap with or without vertical incision. Note that the envelope flap without vertical incision will be minimally invasive but narrow surgical field. (**a**) Without the vertical incision, (**b**) With the vertical incision

flap without a vertical incision will be minimally invasive but narrow surgical field (Fig. 20.7) (Naruse 2021). Strong traction is applied to the tissue to make the surgical field clear in the envelope flap. Also, when setting the incision line for mandibular third molar removal, not only the position of the tooth but also bone milling and tooth division should be taken into consideration.

Other Designs of Flaps (Fig. 20.8)

Envelope Flap

Envelope flaps have no vertical incision to release anteriorly. The distal incision starts from the medial to the external oblique ridge to the middle of the distal line angle of the second molar (Stephens et al. 1983; Szmyd 1971) (Fig. 20.8a). This flap is an application of the concept of a directly above incision performed when removing a tumour, i.e. making a linear incision in the mesiodistal direction just above the impacted mandibular third molar. The visibility of the surgical field depends on how far anterior the gingival sulcular incision is extended, occasionally until the first or second mandibular molar (Elo et al. 2016). The risk of lingual nerve injury can be avoided by swinging the distal incision in the direction of the lateral oblique ridge. However, empirically, it may not be applicable to the deeper impacted mandibular

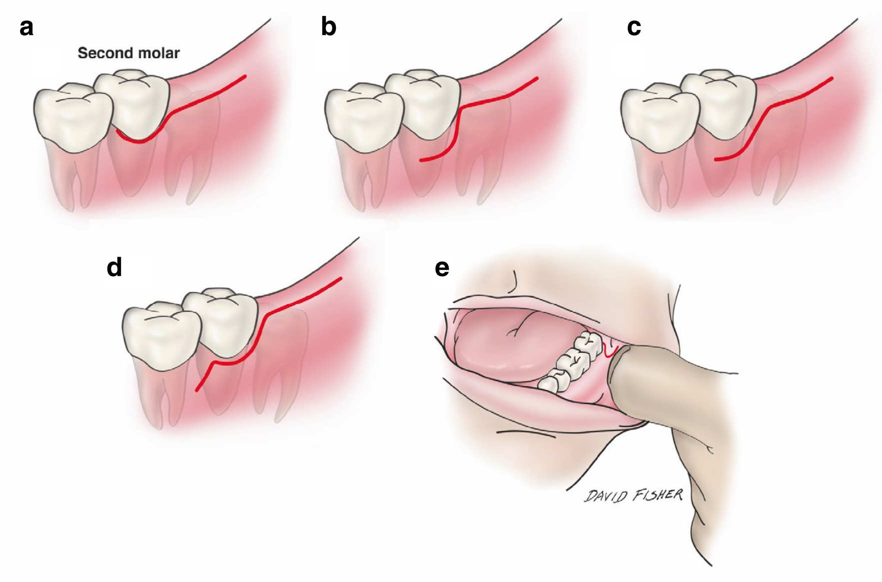


Fig. 20.8 Various flap designs. (**a**) envelope flap; (**b**) Szmyd flap; (**c**) modified Szmyd flap; (**d**) paramarginal flap; (**e**) comma incision

third molar. The operative time required for the suture may be slightly shorter due to no vertical incision (Sandhu et al. 2010).

Szmyd Flap and Modified Szmyd Flap

In 1971, Szmyd advocated the unique flap design, which preserves the buccal gingiva of the second molars and minimizes the bone resorption at this place (Szmyd 1971) (Fig. 20.8b). This flap makes the incision from the external oblique ridge up to the midline of the distobuccal angle of the second molar, similar to the common triangular flap. Then, it is extended from the distobuccal angle of the second molar and to the root apex of the second molar towards the mucogingival line. Rosa et al. examined and compared probing depth, clinical attachment level, and bone level of the second molar between the Szmyd flap and the common triangular flap (Rosa et al. 2002). However, there was no statistically significant difference between both flaps.

Kirtiloğlu et al. reported the modified Szmyd flap to prevent wound dehiscence distal to the second molar during primary wound healing (Fig. 20.8c) (Kirtiloğlu et al. 2007). The distal incision starts from the external oblique ridge and terminates 2 mm behind the second molar. From this point, it is run towards the root apex of the second molar towards the mucogingival line, similar to the original Szmyd flap. They concluded that the modified Szmyd flap had better primary periodontal healing due to the presence of the intact gingiva around the second molar compared to

the buccal-based triangular flap (Kirtiloğlu et al. 2007). Although these flaps may be less invasive than the traditional triangular flap because of the small flap area, access to the surgical field may be difficult, especially at the mesial buccal side of the mandibular third molar.

Paramarginal Flap

The buccal-based triangular flap consists of the vertical incision to release anteriorly, the gingival sulcus incision of the second molar, and the distal incision towards the external oblique ridge. The paramarginal flap is a similar shape to the common triangular flap but is formed while maintaining a distance of 2 mm from the gingival margin (Fig. 20.8d) (Suarez-Cunqueiro et al. 2003). Suarez-Cunqueiro et al. compared the traditional buccal-based triangular flap with the paramarginal flap and demonstrated that the latter have no superiority since eight cases developed wound dehiscences (Suarez-Cunqueiro et al. 2003).

Comma Incision

Nageshwar suggested the buccal comma-shaped incision as for the distolingual-based flap (Fig. 20.8e) (Nageshwar 2002). A surgeon stretches down the buccal vestibule below the preceding second molar as lateral as possible with the index finger or thumb. This incision starts from the deep point of the stretched vestibule posterior to the second molar. Then, the incision runs anteriorly and goes towards the distobuccal gingival crest of the second molar while curving smoothly. Finally, it is extended as a gingival sulcus incision around the distal aspect of the second molar.

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21 Techniques of Mandibular Third Molar Extraction

Puhan He and Joe Iwanaga

Introduction

Surgical removal of mandibular third molars is one of the most common procedures performed by oral maxillofacial surgeons. While there are a myriad of indications for the removal of mandibular third molars, the most common diagnosis is pericoronitis (McArdle et al. 2018). Pericoronitis is a recurrent infection around the third molar in its attempt to erupt against soft and bony tissues. Signs and symptoms of pericoronitis may include pain, foul taste, swelling in soft tissue or face, and trismus. In more serious cases, this infection can spread and result in lymphadenopathy

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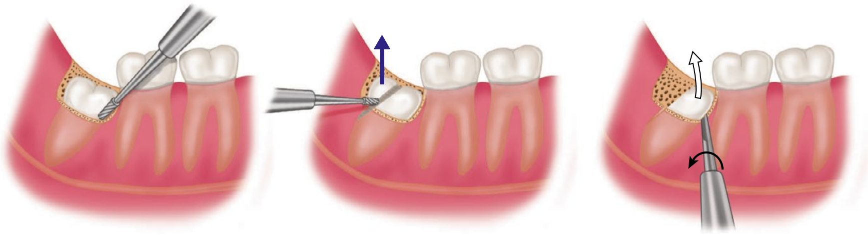


Fig. 21.1 Distal elevation

or swelling that progresses to threaten the airway and involve the submandibular, sublingual, and submental spaces (Fig. 21.1). Other common indications for third molar extractions include non-restorable tooth due to caries, fracture, caries or resorption of adjacent tooth, and pulpal and periapical pathology. Surgery is commonly associated with short-term postoperative pain, swelling, and trismus. Less frequently, infection, alveolar osteitis, trigeminal nerve injuries, and fracture of the mandible may occur (Bailey et al. 2020). While some complications such as infection and development of alveolar osteitis are related to patient comorbidities and social factors, proper surgical technique can minimize rarer complications such as iatrogenic injuries to the trigeminal nerve and its branches as well as fractures.

Principles of Surgical Extraction

Surgical extraction of an impacted mandibular third molar is primarily based on two principles: thorough pre-surgical planning and adequate exposure for proper instrumentation. The head and neck region contain compact and vital structures. In particular, the mandibular third molars are adjacent to important structures including the inferior border of the mandible, the inferior alveolar nerve and artery, as well as the lingual nerve and artery. Permanent damage to the ipsilateral inferior alveolar nerve and subsequent sensory alterations is one of the most litigated injuries (He et al. 2019). As such, pre-surgical planning with panoramic X-ray and subsequent CBCT or CT if high-risk radiographic findings are observed including interruption of the mandibular canal wall, darkening of the third molar roots, and diversion of the mandibular canal among others (Rood and Shehab 1990). Pre-surgical planning may indicate benefits of coronectomy outweighing the risk of complete extraction. The second principle of extracting mandibular third molars is creating adequate exposure. This is achieved by developing a full-thickness mucoperiosteal flap that allows for placement of retractors, drilling equipment, elevators, and forceps for successful delivery of the tooth. A well-placed, toed out Minnesota retractor lateral to the external oblique ridge maximizes visibility for the operator. If the impacted tooth is not too deep, the #9 periosteal elevator may be a versatile tool to help expose the crown by gently removing the superficial layer of the bone covering the tooth with the sharp end of the tool. Visualizing the tooth allows for a better understanding of the orientation and size of the tooth. Further exposure may be warranted

by creating a trough. This is accomplished by removing the bone buccal and distal to the cervical line of the tooth, thereby exposing the crown and allowing for instrumentation. The specific technique for delivering the tooth depends on the angulation of the impacted tooth (Farish and Bouloux 2007).

Extraction Technique by Classification of Mandibular Third Molars

Classification systems of impacted teeth are primarily based on angulation of the third molar along the axis of a second molar that has a normal axis of eruption. Mesioangular impacted third molars account for 43% of all mandibular impacted third molars (Peterson et al. 2003). Horizontally impacted third molars are considered more difficult to remove and account for approximately 3% of all mandibular impactions. Vertical impaction represents about 38% of all mandibular impactions and is more challenging to surgically remove than mesioangular and horizontal impacted third molars. The distoangular impaction is the most difficult to remove but only occurs 6% of the time, most often in partially or fully erupted rather than impacted third molars. In the buccal lingual direction, most third molars are lingually angulated, compared to buccally or transversely oriented. The following describes common strategies of extracting each type of impacted mandibular third molar. In practice, each case is unique, and technique may differ based on the depth of impaction, degree of root formation, age of patient, as well as experience of the provider. The following descriptions hope to expand the operators' armamentarium and repertoire of skills, allowing for versatility and success.

Mesioangular Impaction

An elevator can be used to gently luxate the tooth distally. This separates the PDL fibres that holds the cementum and alveolar bone together and minimizes fracturing of the root tips. Sometimes, distal elevation may be sufficient to deliver the tooth (Fig. 21.1). This can be done by using an elevator alone or by placing a purchase point in the mesial portion of the tooth at the cervical line and using the Crane pick or a Cogswell B elevator to attempt to deliver the tooth as a whole. This author recommends against use of excessive force. Particularly in the case of impacted third molar that have not yet sustained occlusal forces, tremendous forces should not be required to separate the PDL fibres. When the tooth cannot be delivered by distal elevation alone, the tooth should be sectioned such that the path of exit is non-obstructed. The distal portion of the crown can be sectioned diagonally and delivered first. This allows greater room for distal elevation of the remaining tooth and subsequent delivery. Alternatively, a longitudinal section can be performed separating the distal and mesial roots, followed by elevation of the distal half of the crown and root and then the mesial half.

Horizontal Impaction

To minimize mandibular bone removal, horizontally impacted third molars can be extracted by separating the crown and the roots. After adequate exposure of the crown with a bur and/or a periosteal elevator, use the bur to section the crown and roots about 2/3 of the buccal-lingual length to protect the lingual plate. Care should be taken to ensure that the bur does not drift distally. This would result in a section that is larger at the bottom and smaller on top, potentially hindering the path of delivery. An elevator can be used to separate the remainder of the crown and roots. The crown can be sectioned further longitudinally if delivery is difficult, favouring more sections over force. The roots can be delivered with placement of a purchase point at the superior aspects of the upper root and delivered with a Cogswell B elevator or by sectioning and delivering separately (Fig. 21.2).

Vertical Impaction

Similar to mesioangular impaction, younger patients may require only simple elevation with the help of a purchase point to deliver the tooth. If the roots are fused, the distal aspect of the crown can be sectioned to allow delivery of the remainder of the whole tooth. If the roots are divergent, the mesial and distal roots can be separated. If the impaction is deep, a buccal and distal trough can be created to expose the crown. The tooth can be elevated superiorly to allow for access to section the crown in a horizontal fashion. The roots can be delivered together or delivered separately after sectioning with the distal delivered first prior to the mesial root. Care should be taken when sectioning to have sufficient structure/handle above existing bone to allow for elevation and to minimize bone removal.

Distoangular Impaction

These are considered the most challenging both because of access, visibility, and path of delivery. The buccal trough here should expose the crown to the cervical line. Elevation can be initially attempted to allow for severance of the PDL. If mobility is achieved, the whole crown or distal crown can be sectioned from the

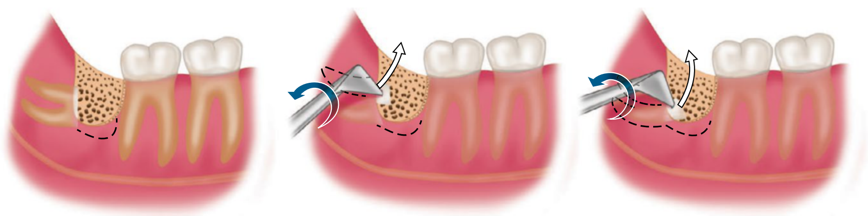


Fig. 21.2 Sectioning and delivering for horizontal impaction

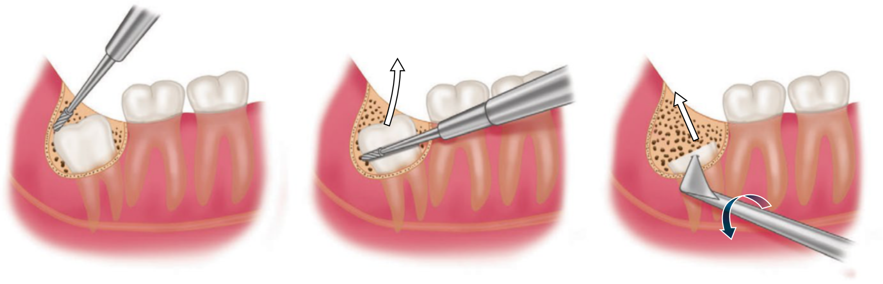


Fig. 21.3 The buccal troughing and whole crown/distal crown sectioning for distoangular impaction

roots (Fig. 21.3). Again, it is preferable to do multiple sections over removing more bone to avoid unintentional fractures or injury. The remaining root and mesial crown can be then elevated and removed – considering additional sections as necessary (Farish and Bouloux 2007).

General Techniques Used

Detailed below are more specifics on the techniques and considerations important for successful delivery of an impacted mandibular third molar.

Troughing

The goal of troughing is to create access for instrumentation with a surgical drill and elevators as well as to widen the hole where the tooth will be delivered. The trough should be made by removing alveolar bone that hugs the third molar using a bur such as the #702. The tip of the bur should be visualized at all times. The buccal interproximal bone between the second and third molar can be removed with care to provide space for the placement of an elevator and allow for distal luxation of the tooth. The operator can consider removing distal alveolar bone to increase space for distal luxation, being conscious that up to 17% of population where the lingual nerve may be at the level of the alveolar crest or higher (Behnia et al. 2000; Kiesselbach and Chamberlain 1984) and 0.15% of cases in the retromolar pad region (Behnia et al. 2000).

Sectioning

It is important to consider the path of exit of the tooth fragments when planning the vertical section. The sectioned piece should be able to be delivered without obstruction. The angle of the cut should be perpendicular or err on angling mesial as the bur travels deeper – in this manner, the tooth fragment would be smaller at the bottom and wider on the top, allowing unimpeded delivery.

Purchase Point

This can also be considered to help with delivery. A Crane Pick or Cogswell B elevator can be used to elevate teeth with purchase points. The placement of the purchase point could encourage elevation rather than further fracture of tooth into fragments. Cogswell B elevator has a smooth surface at the tip and is less likely to cause a fracture, as compared to the Crane Pick which has a flat surface at the four sides of the tip. Delivery of a whole tooth for mesioangular impacted and vertically impacted tooth in patients that are young is often possible with the placement of the purchase point (Farish and Bouloux 2007).

Use of Cryer or Winter Elevators

These elevators allow for application of greater force. However, their use is usually not needed if adequate preparation with the drill and sectioning is made. Risks of application of excessive force include unfavourable root fracture, buccal or lingual bone loss, damage to the adjacent second molar, or even fracture of the mandible. The anatomy of these elevators can be useful in removing bone in a furcation to help deliver a retained root fragment (Farish and Bouloux 2007).

Lingual Split and Lingual Flap

The lingual split or split bone technique, first described by Ward in 1956 (Ward 1956) and later modified by Lewis in 1980 (Lewis 1980), is an alternative to the surgical bur technique described in the previous sections. The goal of this technique is to section a piece of the distolingual bone to facilitate the removal of the impacted tooth, especially those in distoangular orientation. First, exposure of the buccal and lingual aspects of the third molar is achieved by developing buccal and lingual flaps. Mesiobuccal access is created by first making a vertical cut in the buccal bone with a mono bevel chisel distal to the second molar and then a second horizontal cut to join the first posteriorly. The bevel of the chisel is then turned lingually, angling the chisel between vertical and 45 degrees to the second molar and directed towards the contralateral second premolar. The original technique described by Ward involves removal of the fractured lingual plate in this fashion, while Lewis recommends merely displacing the lingual plate. The strategy is not widely used due to the potential risk for temporary and permanent lingual nerve injury as well as patient discomfort. Temporary lingual nerve injury has been reported to be between 0.8% and 20%, and permanent nerve injury between 0% and 1% (Mason 1988; Moss and Wake 1999; Rood 1992; Rood and Shehab 1990). While elevation of a lingual flap is helpful in the lingual split technique, Robinson and Smith (1996) recommended avoiding a lingual flap with the lingual split technique to reduce the frequency of lingual nerve injuries (Fig. 21.4). In a systemic review by Pichler and Beirne

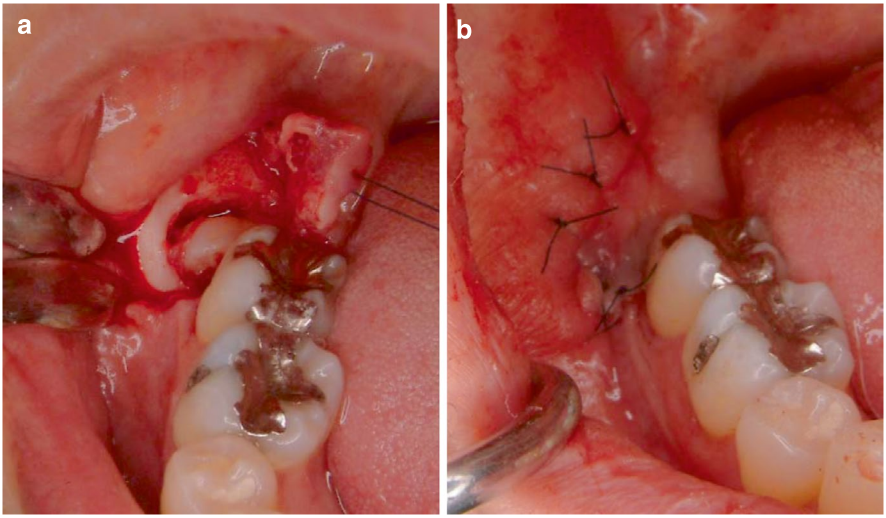


Fig. 21.4 A Lingual flap elevation, B After suturing

comparing lingual split, bur technique with lingual flap, and bur technique without lingual, the incidence of temporary nerve injury was found to be 9.6%, 6.4%, and 0.6%, respectively. The incidence of permanent nerve injury was reported at 0.1%, 0.6%, and 0.2%, respectively (Pichler and Beirne 2001). Notably, a lingual flap with the bur technique should be avoided because of the threefold increase in the incidence of permanent nerve injury.

Lingual Nerve Protection

In the majority of patients, the mean horizontal distance of the lingual nerve to the lingual plate is 2.06 mm, and vertical distance to lingual crest is 3.01 mm (Behnia et al. 2000). Up to 17% of the population of patients have lingual nerves at the level of the alveolar crest or higher (Behnia et al. 2000; Kiesselbach and Chamberlain 1984) and 0.15% of patients in the retromolar pad region (Behnia et al. 2000). Thus, the lingual nerve can be injured in the process of third molar extraction, particularly when developing a flap, during distolingual bone removal or luxation of the tooth. 'Lingual nerve protection' involves an instrument, such as a retractor or Howarth's periosteal elevator, placed between the bone to be removed and the lingual flap which presumably contains the nerve, to protect it from injury. However, some surgeons believe that the placement of the instrument may cause temporary nerve injury (Renton and McGurk 2001), with meta-analysis by Bailey et al. demonstrating an odds ratio of up to 4.18 (Bailey et al. 2020). There was insufficient evidence to determine whether lingual retraction or protection causes permanent altered sensation in the region of the lingual nerve distribution.

Coronectomy

When there is radiographic evidence of intimate relationship between a mandibular third molar and the inferior alveolar nerve, root retention techniques such as coronectomy should be considered (Renton 2012). In the presence of high-risk radiographic signs (diversion of canal, darkening of root, interruption of laminar dura, etc.), surgical extraction of mandibular third molars results in temporary injury in 20% of patients and permanent injury in 1–4% of patients (Howe 1960; Renton et al. 2005; Rood and Shehab 1990; Rud 1983). If the tooth is carious, or if the patient is immune compromised or may have poor healing such as in the case of diabetes, long-term steroid use, chemotherapy, HIV, or history of radiation, the elevated risk of inferior alveolar nerve injury should be discussed, and surgical extraction should be recommended. If the tooth and patient are healthy, coronectomy can be an option. Exposure of the cemental-enamel junction is important to ensure complete resection of crown. This is achieved by adequate exposure, development of a full-thickness buccal mucoperiosteal flap, and trough. A fissure bur is then used to section crown from root below the cemental-enamel junction 2/3 of the buccolingual distance of the tooth. A small elevator can be used to fracture of the crown from the roots while ensuring minimal root mobilization. Eruption of the roots may occur in 2–5% in 2–5 years (Renton 2012). There are no studies with long-term follow-up to assess the adverse effects associated with coronectomy (Bailey et al. 2020).

Germectomy

Germectomy is the removal of third molars prior to the complete development of its roots (Fig. 21.5). A tooth with one-third to two-thirds root development and that has yet to sustain occlusal force, is easier to remove than a tooth with full root development. Additionally, there is often more distance from the inferior alveolar nerve (Farish and Bouloux 2007). However, limited root development leads to a ‘rolling’ of the tooth, which necessitates sectioning in multiple planes for delivery. In a systematic review by Staderini et al., definite indications for early removal or germectomy include morphological abnormalities, Ekman-Wetborg-Julin syndrome, and

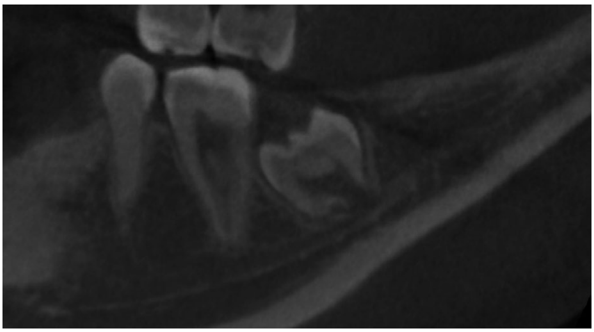


Fig. 21.5 Germectomy

self-mutilating behaviour or recurrent epilepsy (Staderini et al. 2019). Morphological abnormalities represent the majority of patients who undergo germectomy. These include delayed or ectopic eruption of neighbouring teeth, frank pathology or infection, partial soft tissue impacted tooth with risk of severe pericoronitis/decay, and/or root resorption of adjacent second molar. Toothache may trigger or aggravate self-mutilation behaviours in certain conditions that may range from tooth grinding, biting lower lip, tongue, cheek to traumatizing other parts of the body. Medications such as antiepileptics such as phenytoin that causes gingival hypertrophy may put certain patients at taking them at risk of periodontal complications and pain, triggering onset of seizures (Károlyházy et al. 2003). Indications for late removal include orthodontic considerations or in patients with a decreased ability to maintain oral health where the third molars can be used to substitute second molars or used as a retention element for fixed/removable prosthesis (Staderini et al. 2019). In practice, the routine early extraction of third molars is often recommended prophylactically. However, the National Institute of Health and Care Excellence states that the practice of prophylactic removal of pathology-free impacted third molars should be discontinued, particularly in patients who require general anaesthesia for this procedure (Royal College of Surgeons Faculty of Dental Surgery 2020). Ultimately, patient-centred discussions weighing risks versus benefit and collaborative decision-making should be undertaken to ensure maintenance or improvement of quality of life.

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Suturing Following Mandibular Third Molar Extraction

22

Jennifer Caughey and Joe Iwanaga

Introduction

The extraction of impacted or partially impacted mandibular third molars typically requires the creation of a full-thickness mucoperiosteal flap and removal of surrounding mandibular bone due to the obstruction of surrounding teeth, bone, and soft tissue. There remains a difference in opinion in the literature regarding the technique of wound closure and ideal suture material to be used after removal of mandibular third molars.

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Material of Suture

Various types of suture materials are utilized intraorally when closing mandibular third molar flaps. 3-0 black silk is the most commonly utilized non-resorbable suture intraorally. It is a polyfilament suture, making it easy to tie and less irritating to the patient's tongue. Additionally, the black colour allows for easy removal of the suture 5–7 days after placement (YJOMS_v73_i8_sS_COVER.indd n.d.).

The most common types of resorbable sutures are monofilament chromic gut, composed of the serosal surface of sheep intestine and braided synthetic suture materials, such as polyglycolic acid and polylactic acid. Braided sutures are easier to handle and tie and less irritating to the patient's tongue and do not easily come untied, whereas monofilament sutures, though more difficult to tie and handle, do not produce and retain as much saliva and bacteria (YJOMS_v73_i8_sS_COVER.indd n.d.).

Sala-Perez et al. evaluated the utilization of resorbable versus non-resorbable sutures for closure of third molar extraction sites and found that the use of the resorbable suture, Monocryl Plus, exhibited significant anti-bacterial effects when compared to the non-resorbable silk suture, though the post-operative infection rate was nearly zero with both types of sutures (Sala-Pérez et al. 2016). Bucci et al. compared bacterial colonization of different types of suturing material used after third molar extractions, specifically silk, monofilament, and polyglycoside, and found that the amount of analysed cocci and bacilli showed the silk sutures to exhibit the highest level of retention and monofilament the least (Minerva Stomatologica 2017).

When deciding what type of suture material to utilize when closing the extraction socket and create full-thickness mucoperiosteal flap, it is important to consider factors such as patient comfort, as well as ease and timing of follow-up. Utilization of a non-resorbable suture inherently requires an additional follow-up visit, which may not otherwise be necessary in a patient following the routine post-operative course of healing. Additionally, using a non-resorbable suture has been demonstrated to exhibit greater antimicrobial properties when compared to non-resorbable sutures.

Primary Versus Secondary Closure

Closure of third molar extraction sites can be accomplished through complete closure of the mucoperiosteum and healing via primary intention or healing via secondary intention through leaving a partial open window, traditionally distal to the existing second molar. Ma et al. conducted a meta-analysis on the efficacy of secondary closure technique after extraction of mandibular third molars and found that patients whose incisions had been closed primarily compared to those who were closed secondarily, by leaving a 5–6 mm wedge of mucosa distal to the second molar, exhibited less post-operative pain, as well as less swelling and trismus (Sala-Pérez et al. 2016) (Fig. 22.1). Similarly, Bello et al. found that partial instead of

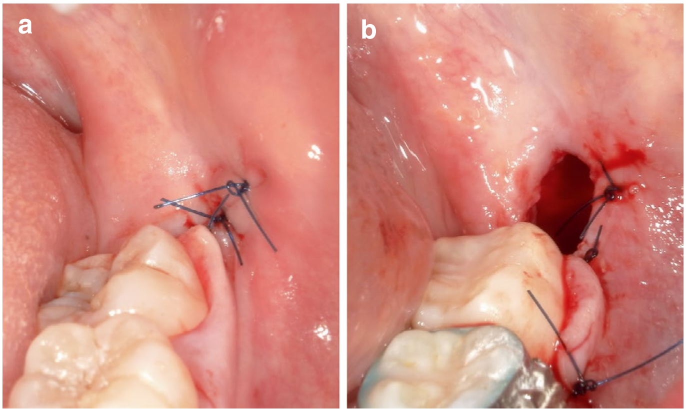


Fig. 22.1 Primary closure (**a**) and secondary closure (**b**)

complete closure of the third molar incision was associated with more post-operative morbidity in the setting of higher amounts of reactionary bleeding associated with the open tissue (Bello et al. 2011). Additionally, primary closure of the flap has traditionally been known to help avoid suture dehiscence and improve overall wound healing (Jakse et al. 2002).

Pasqualini et al. compared primary and secondary closure techniques in 200 patients through evaluation of post-operative pain and swelling and contrarily found that swelling was significantly worse in the group where the socket was closed primarily, with pain and swelling also being less severe with secondary healing (Pasqualini et al. 2005). Similar studies have concluded that patients that received secondary instead of primary closure had a significantly lesser amount of pain and swelling post-operatively (Danda et al. 2010) (Osunde et al. 2011).

A prospective randomized study conducted by Osunde et al. evaluated the effect of allowing for healing through only secondary intention on post-operative pain, swelling, and trismus in lower third molar surgery and found there to be significantly less pain, swelling, and trismus at 24 h and 48 h post-operatively compared to the flaps that were repaired with sutures (Osunde et al. 2012). Bielsa et al. similarly found that patients experienced less pain, swelling, and trismus after extraction of a partially impacted third molar when healing took place by secondary intention through approximation of the flap margins when compared to healing by primary intention through flap reposition and suturing (Sanchis Bielsa et al. 2008).

It is important for the surgeon performing extraction of third molar sites to evaluate the size of the created flap and remaining extraction socket when determining if closure should be achieved primarily or through secondary intention. Patients that may be more prone to increased amounts of post-operative bleeding or poor wound healing may have extraction sites closed primarily, whereas those without any significant comorbidities could potentially have the option of healing via secondary intention.

Suturing Techniques

If electing to proceed with primary closure of a flap created for extraction of mandibular third molars, there are multiple techniques that may be used. The simple interrupted suture is preferred by many surgeons due to ease of technique and efficiency, particularly when closing the commonly used envelope flap with a distal release (Jakse et al. 2002) (Fig. 22.2). An anchoring suture may additionally be used as means of closing a flap located in an edentulous area mesial or distal to a tooth and is therefore best utilized when creating a mesial or distal wedge, as this technique closely approximates the facial and lingual portion of the flap to the exposed tooth or bone (Takei and Carranza 2012) (Fig. 22.3).

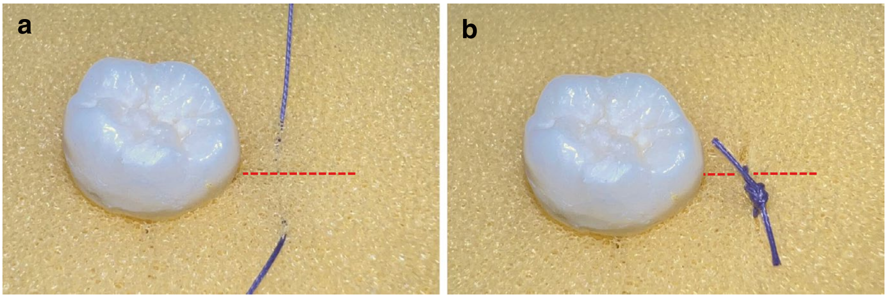


Fig. 22.2 Simple interrupted suture before (**a**) and after (**b**) the knot. Dotted lines: incision lines

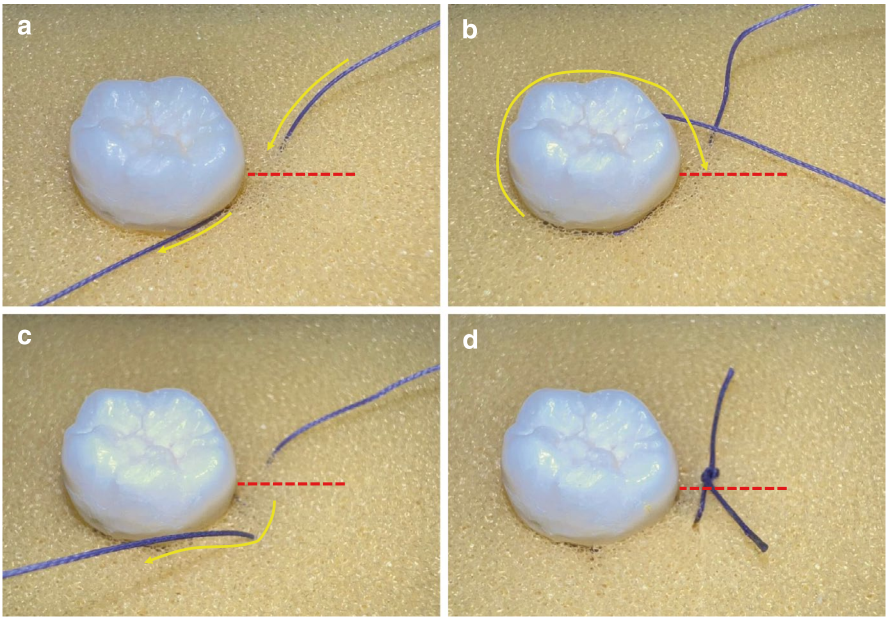


Fig. 22.3 Anchoring suture. The needle pierces the mucosal surface (**a**), the suture wraps around the tooth (**b**), and then the needle penetrates the deep mucosa (**c**). Finally, the knot is tied (**d**). Yellow arrows, needle directions; dotted lines, incision lines

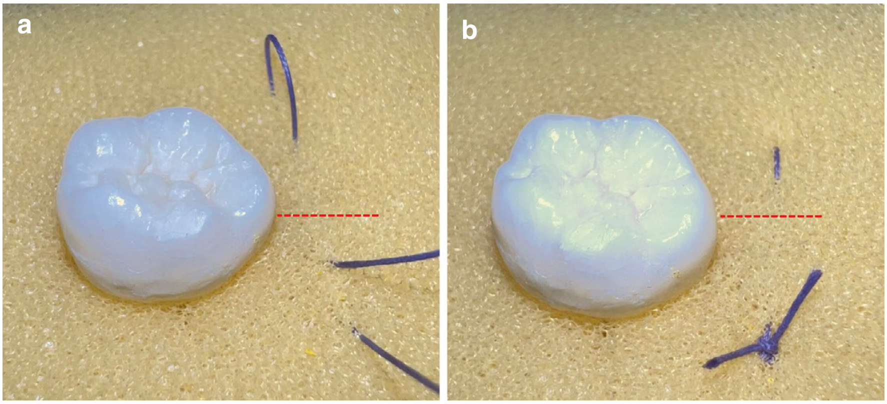


Fig. 22.4 Vertical mattress suture before (**a**) and after (**b**) the knot. Dotted lines, incision lines

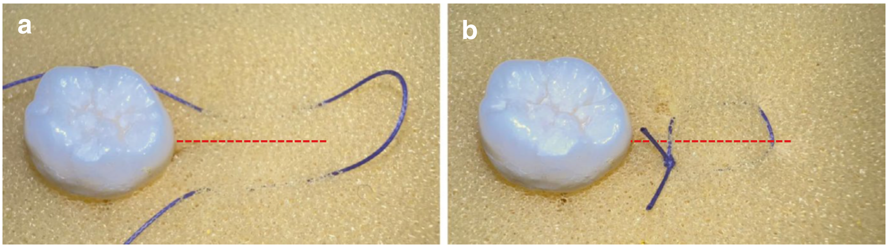


Fig. 22.5 Horizontal mattress suture before (**a**) and after (**b**) the knot. Dotted lines, incision lines

Delemi et al. compared three different methods of suturing technique for primary closure of envelope flaps created for extraction of mandibular third molars, simple interrupted, vertical mattress technique, and anchoring technique, and found no significant difference in post-operative pain and swelling between the three methods (Delemi 2016) (Fig. 22.4). Cetinkaya et al. compared utilization of simple interrupted suture compared to anchoring suture on the periodontal health of the neighbouring second molars following extraction of mandibular third molars and found the anchor suture to be a superior technique in regard to the prevention of any associated periodontal issues (Cetinkaya et al. 2009).

Acar et al. evaluated the use of horizontal mattress versus simple interrupted sutures on post-operative wound healing and complications following surgical extraction of impacted mandibular third molars and found there to be no statistical difference between the two different techniques in regard to post-operative pain, trismus, and swelling, though there was less incidence of dehiscence in the horizontal mattress group (Acar et al. 2017) (Fig. 22.5).

Ege and Najafov compared closure of surgical third molar extraction sites by simple sutures and utilization locked versus unlocked knots (Fig. 22.6). This group found that the unlocked knot group fared significantly better in terms of

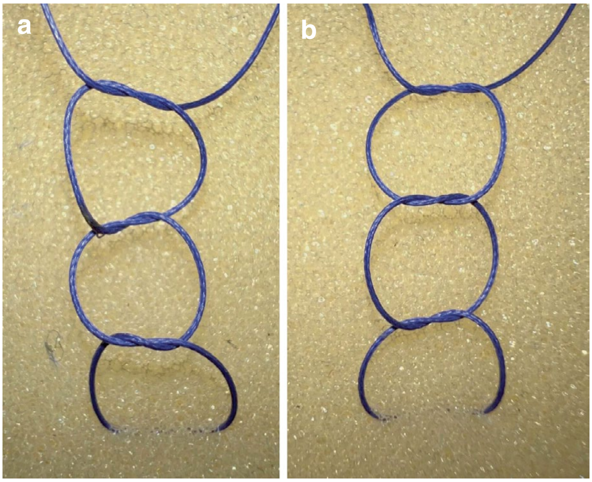


Fig. 22.6 Locked nots (**a**) and unlocked knots (**b**)

post-operative pain, swelling, and trismus (Ege and Najafov 2020). Patients subsequently were able to chew better on the side of the unlocked suture and found a quicker return to chewing function. It was determined that the decreased in post-operative morbidity in the unlocked group was likely attributed to the loosening of the suture over time, allowing for increased wound drainage.

Conclusion

Use of various materials, as well as particular suturing and closure techniques, has been demonstrated by a number of studies to have varying outcomes in regard to post-operative complications following surgical extraction of third molars, such as pain, swelling, and trismus. Additionally, there are a variety of confounding factors that may contribute to the outcomes listed above, such as patient factors, including various comorbidities and post-operative care, as well as surgeon factors, including operative experience, duration of surgery, and difficulty of the extraction. It is important for the surgeon to consider these factors, as well as advantages and disadvantages of type of suture material, technique of closure, and method of healing, following extraction of third molars.

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Part IV

Preoperative Evaluation

What to Evaluate on Radiography

23

Yuki Arai, Chiaki Arai, Ichiro Hatakeyama, and Joe Iwanaga

Introduction

The degree of difficulty of extraction of an impacted mandibular third molar is to some extent predictable on panoramic radiographs. Because there are understandably some limitations to acquiring details from panoramic radiographs only,

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computed tomography images in combination with panoramic radiographs provide significant information.

Evaluation in Panoramic Radiograph

Relationship Between the Mandibular Canal and the Root of the Mandibular Third Molar

It is impossible to visualize the three-dimensional overlapping of the mandibular canal and roots of a mandibular third molar by using only a panoramic radiograph. However, panoramic radiographs are sufficient as screening images in most cases if there is no overlap between the mandibular canal and the root of the mandibular third molar.

Rood's Seven Radiographic Signs (Rood and Shehab 1990)

As shown in Chap. 1, of the Rood's seven signs on panoramic radiograph, "interruption of the white line of the canal", "darkening of the root", and "diversion of the canal" are significantly related to the risk of inferior alveolar nerve injury (Su et al. 2017). Therefore, when operators see these three signs preoperatively on panoramic radiography, CT should be obtained (see Fig. 2.1 in Chap. 2). However, the authors recommend CT even if the three signs are not seen and if any overlapping of the canal and tooth is seen.

Pell and Gregory Classification (Gregory and Pell 1933)

1. Position: the depth of impaction (see Fig. 2.2 in Chap. 2)

   It is relatively easy to extract a mandibular third molar located in a shallow position. It is more challenging if the tooth is located deep in the mandible because bone removal would be needed. According to the classification of position based on the occlusal plane of the second molar tooth and the cervical level of the tooth, the difficulties are increased more and more in B vs. A and C vs. B.
2. Class: the distance from the anterior margin of the ascending mandibular ramus (see Fig. 2.2 in Chap. 2)

   According to the Class classification I–III based on the distance between the anterior margin of the ascending mandibular ramus and the distal surface of the mandibular second molars, the shorter distance makes the level of difficulty higher (Class II vs. Class I or Class III vs. Class II). The reasons are the increase in the amount of bone removal due to the deep degree of impaction, the difficulty in handling the instruments, and so on.

Winter's Classification; Angle of Impaction of the Mandibular Third Molar (Winter 1926)

The classification of Winter is based on the angle between the long axis of the third molar and the long axis of the mandibular second molar. The angle should be considered before the operation because the tooth axis influences the degree of extraction difficulty. Among the angles of the mandibular third molar, vertical (shallow position) and slight mesioangular positions are not difficult. However, the degree of difficulty is higher in some cases even if the vertical position of the mandibular third molar, e.g. a tooth with multiple roots, a tooth without a crown, because Winter's classification is just ruling regarding only angle. In addition, it is quite difficult to extract the tooth which is completely impacted in the bone even if vertically. Therefore, we must judge the difficulty from not only the angle but also from the impacted degree. The degree of extraction difficulty and the risk of nerve injury are increased in the case of distoangular, inverted, or linguoangular impacted mandibular third molars.

Root of the Mandibular Third Molar

1. Single root and multiple roots

Tooth extraction is easier for a tooth that has a single versus multiple roots. The procedure becomes more complicated with multiple roots due to the necessity of root separation in most cases, although root separation is not always necessary even in cases of multiple roots with parallel or short roots.

2. Curved root

The risks that might occur in the extraction of a curved root include failure of dislocation, fracture of the root apex, and unremovable even after dislocation of the root, all as a consequence of loading the extraction force in an incorrect direction. Preoperatively, the appropriate direction of loading and the position of root separation should be considered in light of the direction of the root curve. It is quite difficult to remove the root apex once the root is fractured.

3. Hypercementosis of the root apex

Hypercementosis of the root apex often causes difficulty in the case where the tooth is not dislocated by the general procedure of tooth extraction. There are two different ways to make it work, root separation or bone removal. There is no clear criterion for deciding which is a better method, and bone removal might lead to more postoperative complications such as bleeding.

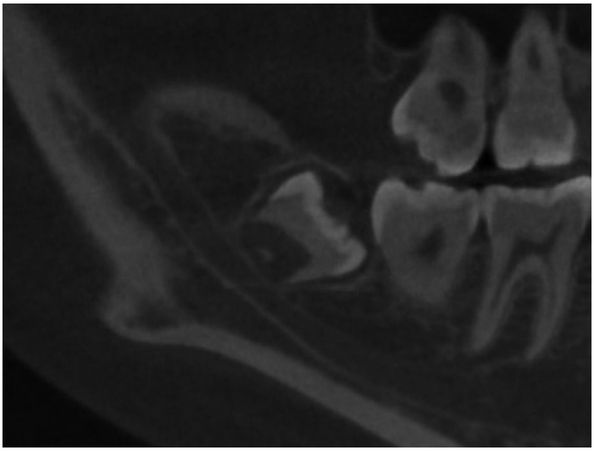


Fig. 23.1 Immature root of the third molar

4. Immature root

It is reported that the risk of inferior alveolar nerve injury is very low with extraction of the immature root. The extraction of the immature root is often easy. On the other hand, it is occasionally difficult to take out the tooth with no root from the tooth socket because the crown rotates in the bone (Fig. 23.1). Therefore, it is necessary to excavate enough bone before the extraction or to section the crown carefully.

Tooth Axis of the Mandibular Second Molar

The tooth axis of the adjacent tooth (mandibular second molar) is often forgotten but is important. The difficulty of crown removal after crown sectioning is predicted by observing the tooth axis of the second molar. The mesioangulated second molar makes securing a sufficient surgical field easier so that the separation of the tooth crown and removal of the tooth crown are easy. On the other hand, the distoangular mandibular second molar creates a blind spot in the surgical field so that the crown removal becomes more difficult. Therefore, the crown might be sectioned into multiple pieces.

Sharpness of the Root

If the border between the root and alveolar bone is unclear, the root can be ankylosed to the surrounding alveolar bone. When the tooth is ankylosed, the procedure can be more challenging due to the difficulty of dislocation. If the surrounding bone or tooth root needs to be drilled, unexpected bleeding from the bone could occur. If the root is ankylosed, the operation time is often longer than normal.

Evaluation in Cone Beam Computed Tomography (CBCT)

Relationship Between the Mandibular Canal and the Roots of the Mandibular Third Molar

Three-dimensional relationship (buccolingual or superoinferior) between the mandibular canal and roots of the mandibular third molar influences the loading direction to dislocate and remove the tooth.

Form of Mandibular Canal of Coronal CBCT Images

The proximity between the mandibular canal and the root of the mandibular third molar can be determined by confirming the coronal form of the mandibular canal (round, oblong, teardrop, and dumbbell form; see Fig. 7.7 in Chap. 7). As stated previously, the risk of nerve injury becomes higher in cases where the shape of the mandibular canal is a teardrop or dumbbell.

Form and Number of Tooth Root

The form and number of the root are observed better on CBCT images compared to panoramic radiography. Actually, we often see cases with single or double roots on a panoramic radiography but three or more roots on a CBCT image of the same patient.

Thickness of the Lingual Cortical Bone

Sometimes, the tooth root or crown of the mandibular third molar penetrates the lingual cortical bone. In these cases, the thickness of the lingual cortical bone must be confirmed by using CBCT because there is a risk of accidental displacement into the floor due to excessive force. Another risk is lingual nerve injury during tooth sectioning and removal of the surrounding bone. When the lingual cortical bone is not observed on CBCT images, we should consider that there is no cortical bone on lingual side. Even if there is lingual cortical bone but the thickness is <1 mm, the lingual nerve should be considered to run very close by.

Existence of Retromolar Canal

The retromolar canal is one of the variations of the mandibular canal referred to in Chap. 1 (see Fig. 1.17 in Chap. 1). It should not be an issue when the retromolar canal opens far from the surgical field; however, it could be an issue when the

retromolar canal is in the surgical field or close to it. In this case, traumatic procedures might result in excessive bleeding.

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Advanced and Difficult Cases

24

Chiaki Tsutsumi-Arai, Joe Iwanaga, and Ichiro Hatakeyama

Introduction

In the previous chapters, potential complications caused by the third molar extraction have been discussed. However, not all of the readers of this book can respond to an emergency, so it might be more practical to perform extractions of selected cases unless the readers are trained oral surgeons.

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What mandibular third molar (difficulty, risk) should I treat in my practice?

This is a frequently asked question. But it is difficult to draw a clear line because of the difficulty of cases as it greatly depends on the surgeon's experience and skill. In addition, there are a number of factors to be considered when deciding if the mandibular third molar is to be removed by a general practitioner or not. In this chapter, we will revisit five points to be considered before extraction.

Excessive Dental Phobia

Many patients who have a negative feeling of third molar extraction blindly believe the negative information about the extractions. Before the surgery, it is important to relieve any anxiety and fear by giving the patient enough explanations. The treatment for patients who have dental phobia can be performed under intravenous sedation (IVS) (Yoon and Kim 2016), and in patients with severe dental phobia, the procedure may be performed more appropriately under general anaesthesia than IVS (O'Halloran 2013).

A Perforation of the Lingual Cortical Plate with Close Proximity to the Mandibular Canal

In cases of the third molars perforating the lingual cortical plate into the floor, holding the lingual side with fingers during the extraction might help prevent the tooth migration into the floor of the mouth (Fig. 24.1). When the third molars lie in close

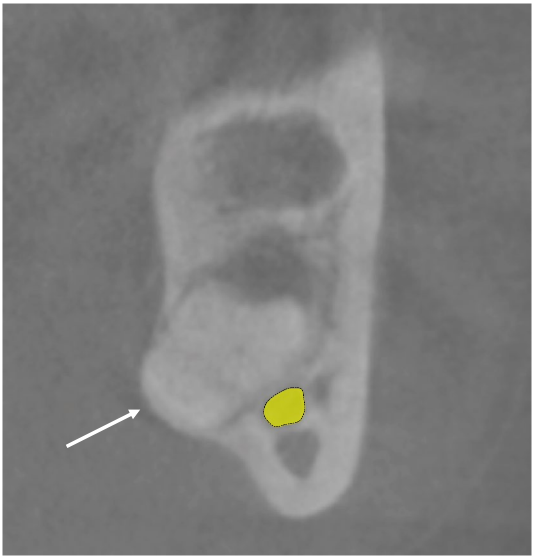


Fig. 24.1 Mandibular third molar perforating the lingual cortical plate into the floor (arrow) with close proximity to mandibular canal (yellow area)

proximity to the mandibular canal, we should consider the risk of bleeding as well as nerve injury (Kieser et al. 2005; Aljunid et al. 2016). If bleeding occurs in the extraction socket with perforation of the lingual cortical plate, serious intra- and postoperative complications such as airway compression due to hematoma might occur. Even if bleeding seems to be stopped, bleeding can occur on the patient's way home or after returning home. Lingual perforation with close proximity to the mandibular canal can be a good criterion for referring patients to an oral surgeon.

Potential Failure of the Local Anaesthesia

If it seems that the local anaesthesia (inferior alveolar nerve block and infiltration anaesthesia) might result in failure due to the close relationship between the mandibular canal and third molars, deeply positioned teeth, or bone sclerosis by chronic inflammation (Loureiro et al. 2020), surgery under general anaesthesia needs to be considered.

Dentigerous Cysts

If a translucent radiography image is seen around the third molars, this could be a dentigerous cyst which many general practitioners may experience (Fig. 24.2). Also, the images might show an ameloblastoma or odontogenic keratocyst that are together the second most common findings following dentigerous cysts. In these cases, it is difficult for the general practitioner to treat. When surgery is performed,



Fig. 24.2 Translucent radiography surrounding the mandibular third molar which could be a dentigerous cyst

even if the image seems like a dentigerous cyst, the specimen needs to be sent for histopathological examination. It has been reported that dentigerous cysts can be accompanied by cancer in 1–2 patients out of 1000 (Bodner et al. 2011; Zapała-Pośpiech et al. 2013).

Patients with Serious Gag Reflex

The gag reflex is mainly caused by physiological and psychological factors. Physiological reflexes are defensive or protective responses. On the other hand, psychological reflexes are induced by extreme dental-related anxiety (Randall et al. 2014). In patients with a severe gag reflex, only a slight stimulation of the anterior parts of the oral cavity can cause the reflex. They can usually swallow foods without gagging when they have meals, so it is believed that their gag reflex can be induced by psychological factors (Randall et al. 2014). There are some ways to reduce gagging such as using small instruments, breathing through the nose, using a saliva ejector, and keeping the patient relaxed. If the patient has a severe gag reflex, surgery under IVS might be preferred. However, extraction under general anaesthesia might be necessary in patients with a serious gag reflex.

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Other Preoperative Conditions

25

Eiji Iwata and Joe Iwanaga

Introduction

The preoperative examinations including radiographic evaluations have been described in the previous chapters. In this chapter, clinical scenarios that we often encounter, i.e. trismus, caries/ acute pulpitis, pericoronitis/severe cellulitis, and incomplete extraction of mandibular third molar, will be discussed.

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Trismus

Trismus is classified into inflammatory, neoplastic, articulated, traumatic, muscular, scarring, and neurological depending on the cause (Santiago-Rosado and Lewison 2020). Locally, there are causes such as morphological and functional disorders of the temporomandibular joint, jawbones, oral mucosa, muscles for mastication, and innervating nerves. Systemic diseases such as epilepsy and Parkinson's disease, autoimmune diseases such as scleroderma and rheumatoid arthritis, and immune reactions such as chronic graft-versus-host disease (GVHD) can also result in trismus. Therefore, the cause of trismus needs to be assessed before extraction of the tooth (Santiago-Rosado and Lewison 2020). If trismus is present, the surgical view and working space could be insufficient. Depending on the degree of the trismus, unfavourable complications might occur such as displacement of the tooth into floor of the mouth (Masui et al. 2021). If the patient has trismus, it can be challenging to retrieve the displaced fragment. When trismus is caused by muscle issues, general anaesthesia with muscle relaxants might help to open the mouth wider. A mouth opener could also help the patients open their mouth. The dental turbine handpiece with a smaller head could also help when dividing the tooth. When using dental turbine handpiece with high pressured air, the risk of subcutaneous emphysema always needs to be considered (Fig. 25.1). After extraction of the mandibular third molar in a patient with trismus, cheilosis angularis caused by the retractor or dental mirror or a burn of the corner of the mouth from the heat of the cutting tools is occasionally observed (Fig. 25.2). Therefore, the operator and assistant should pay attention to the corner of the mouth during extraction.

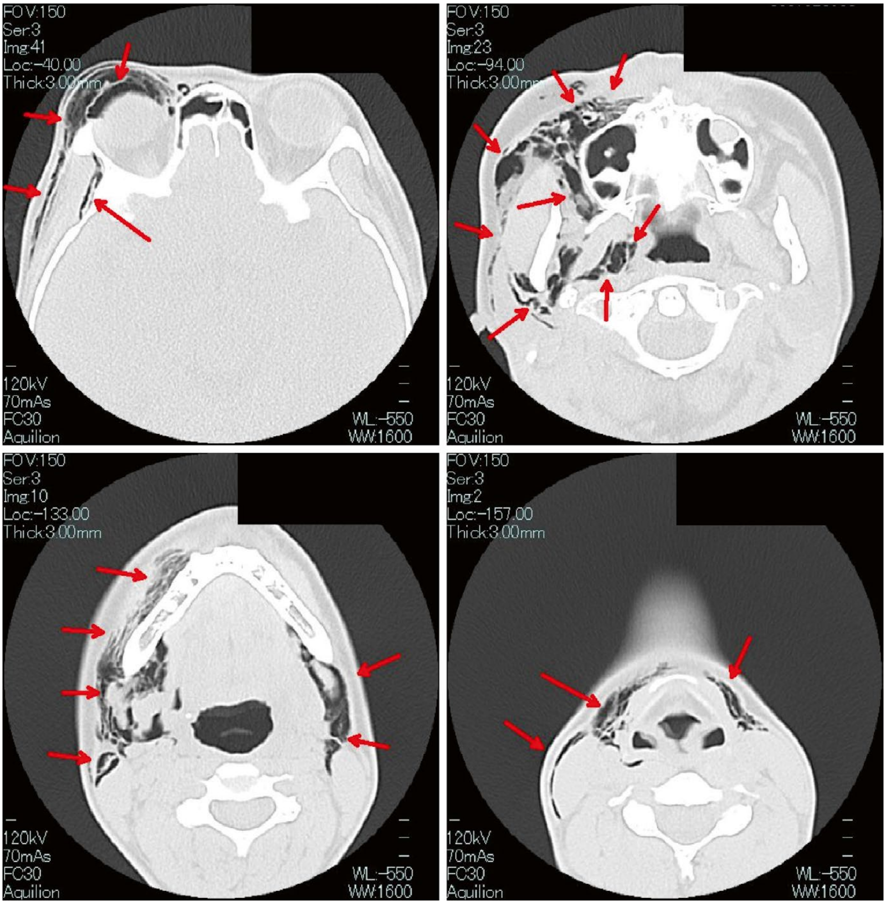
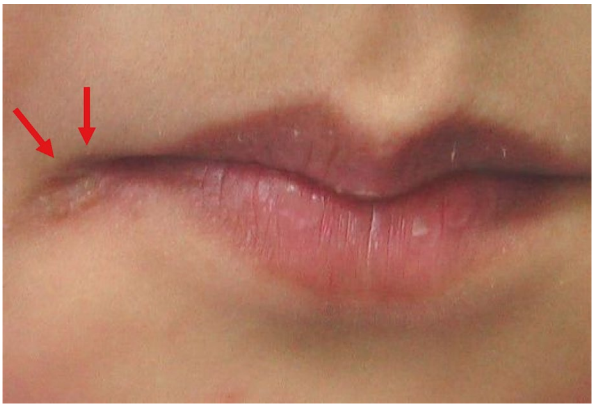


Fig. 25.1 CT imaging of subcutaneous emphysema (SE). Note SE spread to the orbit level superiorly and thyroid cartilage level inferiorly

Fig. 25.2 Cheilosis angularis



Caries/Acute Pulpitis

The mandibular third molars are often accompanied by dental caries. When acute pulpitis is present, extraction can be more difficult (Fig. 25.3). The pain is commonly described as a severe dull throbbing ache. As local anaesthetics are weak bases that exist within an equilibrium between ionized and unionized forms (Dale and Rang 2007), acidic environments caused by inflammation favour the production of ionized particles, which in turn reduces local anaesthetic activity and vice versa. Some have dubbed this the infamous 'Hot Tooth', as a testament to its symptoms, but it has gained more notoriety for its inability to be effectively anesthetized. Hargreaves reported that the success rate of the inferior alveolar nerve blockade for acute pulpitis is about eight times lower than for the tooth without symptom (Hargreaves and Keiser 2002). In addition, if the tooth crown is largely lost by dental caries, larger amounts of bone removal might be required than a tooth without caries (Fig. 25.4). This can result in worse postoperative inflammation including pain and swelling. We have patients take pain medicine such as acetaminophen an hour before the procedure and use more anaesthetics solution than usual.



Fig. 25.3 Panoramic view of acute pulpitis on horizontally impacted third molar



Fig. 25.4 Panoramic view of deep caries on mesioangular third molar

Pericoronitis/Severe Cellulitis

Pericoronitis is an inflammatory condition caused by an increase in the number of bacteria, mainly anaerobic, in follicle around the crown during tooth eruption (Sixou et al. 2003). It generally does not arise in teeth that erupt normally. Reports in the literature indicate that partially erupted mandibular third molars are more prone to present pericoronitis involvement (Punwutikorn et al. 1999). This can be explained by the ease of food impaction between the tooth and the surrounding soft tissues, e.g. follicle around the crown, providing a favourable environment for microorganisms' colonization and, consequently, inflammation (Hazza'a et al. 2009). As a general rule, the extraction should not be performed under acute inflammation. The antibiotic such as metronidazole or penicillin to extinguish acute dental infections is recommended. For patients who are allergic to penicillin, erythromycin is the second choice. These are all active against anaerobic bacteria, which are the predominant cultivable microflora found in pericoronitis and are the first-line antibiotics of choice. There are two reasons to avoid extraction during acute inflammation. One reason is that the acidity increases in the inflamed area preventing local anaesthesia (Ueno et al. 2008). Indeed, it reported the success rate decreasing to 65–69% for infiltration anaesthesia and 58–76% for inferior alveolar nerve block (Sood et al. 2014; Poorni et al. 2011).

Another reason is the risk of causing infection including bacteraemia and septicaemia after the extraction of the teeth with acute infection. If the infection spreads towards anatomical spaces of the head and neck, it could lead to trismus, Ludwig's angina, airway obstruction, and life-threatening conditions such as mediastinitis and necrotizing fasciitis (NF) that might result in sepsis (Ventä et al. 1993; Kavarodi 2011).

In our hospital, out of 56 patients who had abscess or gas production in more than one anatomical space in the neck (severe cellulitis), 24 (42.8%) resulted from the mandibular third molar, and of these, 18 patients had pericoronitis. This result indicates that mandibular third molar pericoronitis could develop to severe cellulitis including NF. Moreover, 11 out of 56 patients (19.6%) experienced severe cellulitis after tooth extraction, and 6 (54.5%) were after mandibular third molar extraction. Therefore, postoperative infection as well as the pericoronitis should be considered.

Case Presentation #1 Pericoronitis/Severe Cellulitis

Here we present a case with severe cellulitis from mandibular third molar pericoronitis. A 57-year-old female presented to our hospital with severe swelling of her right mandible, severe trismus, and odynophagia. The panoramic view showed an impacted mandibular third molar surrounded by radiolucent area (Fig. 25.5). The contrast-enhanced computed tomography (CT) imaging revealed a large abscess formation in the right masticator space (Fig. 25.6). Under the diagnosis of severe cellulitis due to the right mandibular third molar pericoronitis, the patient was hospitalized and underwent intravenous antibiotic treatment with ampicillin-sulbactam. In addition, emergency abscess drainage was performed under general anaesthesia. The patient recovered 19 days later and was discharged from the hospital.

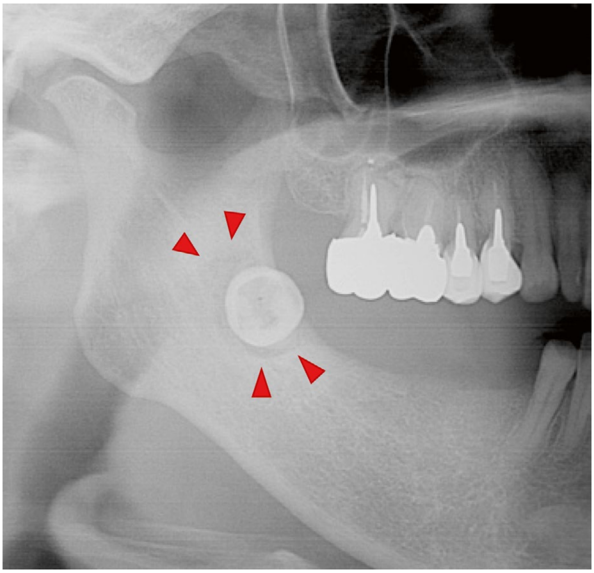


Fig. 25.5 Panoramic view of impacted third molar surrounded by radiolucent area (red arrowheads)

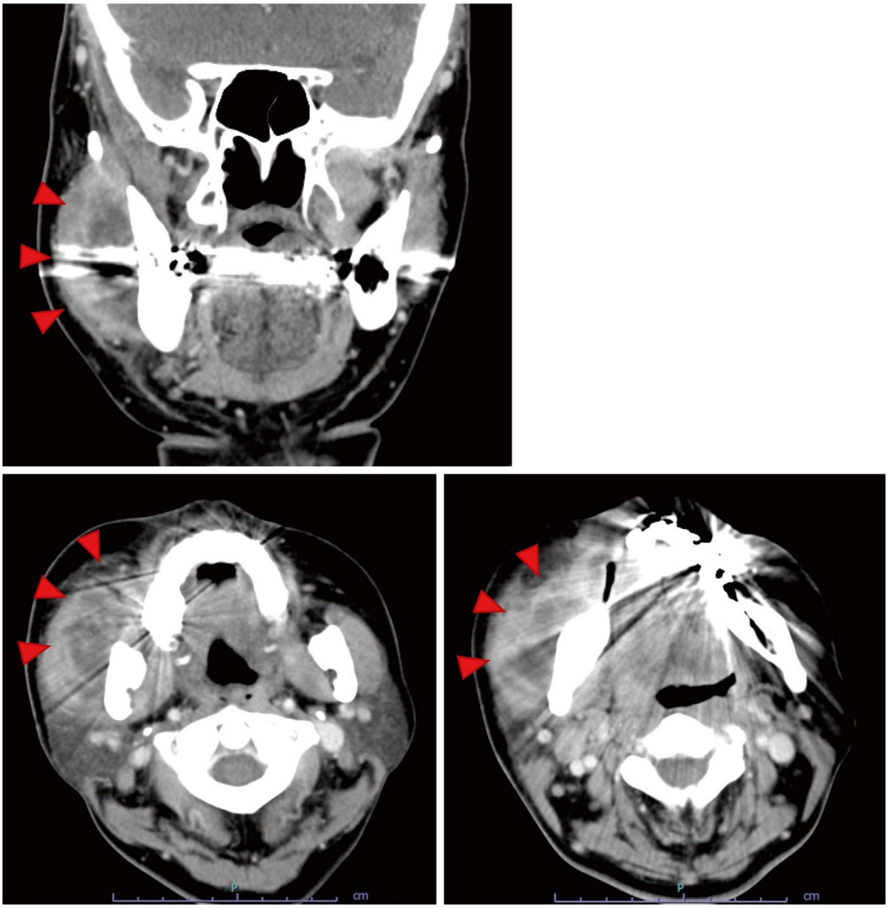


Fig. 25.6 CT imaging of severe cellulitis. The contrast-enhanced CT images revealed a large abscess formation in the right masticator space (arrowheads). The airway was deviated to the left side due to severe inflammation

Incomplete Extraction of Mandibular Third Molar

We occasionally encounter incomplete extraction of the mandibular third molar and see the tooth fragment left in situ in panoramic radiography or CBCT. These are usually found by accident on imaging or if the patient is referred by the patient's home dentist. Here is the list of items to know which might help the second/retrieval surgery to complete the extraction.

- When was the first surgery performed?
- Ask a patient if the first surgery was done under either local or general anaesthesia.
- Did the anaesthesia work if it was a local anaesthesia (if surgery was incomplete because of pain)?

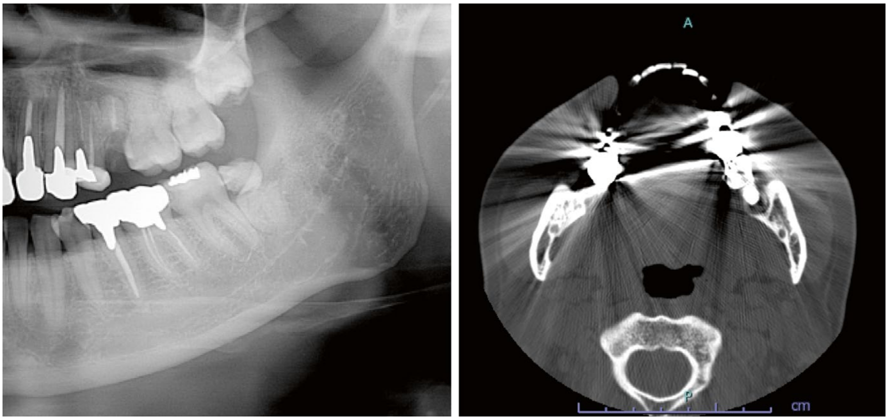


Fig. 25.7 Panoramic view and CT images of the left mandibular third molar showing the extraction is incomplete (tooth fragment is still in situ)

- Perform a CBCT to see the third molar three-dimensionally, e.g. location of the remaining fragment, thickness of the lingual cortical plate, etc. (Fig. 25.7).

Surgical Instrument Breakage During Third Molar Extraction

Breakage of a surgical instrument during a third molar extraction is mostly associated with surgical burs. Inappropriate use of the instruments might result in such breakage (Matsuda et al. 2014). As all instruments are foreign bodies, these broken pieces can cause infection.

Case Presentation #2 Surgical Instrument Breakage

Here we present a case of the breakage of a surgical instrument during the mandibular third molar extraction. A 23-year-old female underwent the extraction of her right mandible third molar in a general dental practice. Unfortunately, the high-speed dental hand-piece bur broke during the extraction, and the patient was referred to our hospital. The panoramic radiography showed a small piece of the bur near the third molar socket. In addition, CT imaging showed a part of the lingual cortical bone was perforated and the foreign body existed within the soft tissues (Figs. 25.8 and 25.9). The patient was informed of the risks of the lingual nerve injury, unsuccessful removal, and the risk of potential infection caused by conservative treatment. As the CT images show, a part of the lingual cortical bone was perforated, and the foreign body existed within the soft tissues. Retrieval was performed, and no postoperative complications including lingual nerve injury were reported (Fig. 25.10).

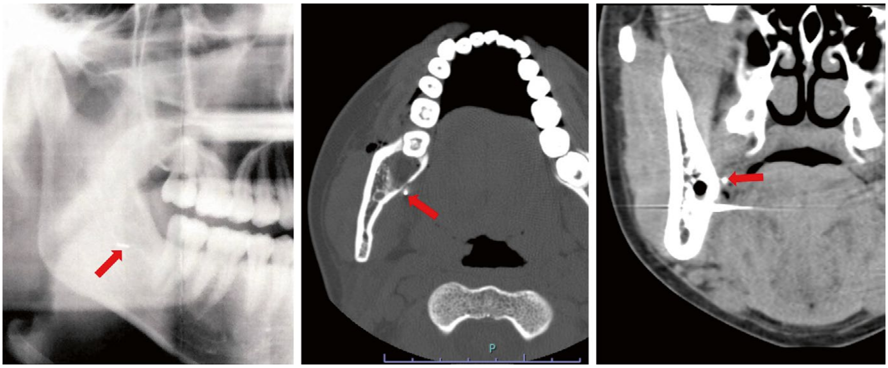


Fig. 25.8 Panoramic view and CT images of broken surgical bur. Note that the lingual cortical bone is perforated in axial view (middle image). Arrows, displaced broken surgical bur

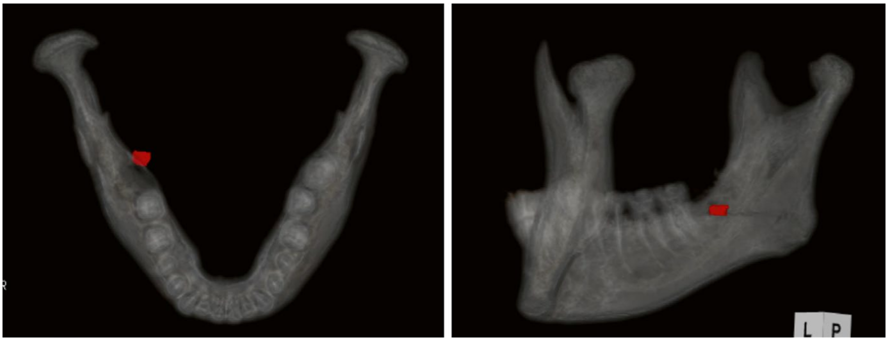


Fig. 25.9 Reconstructed 3D CT images of the displaced broken surgical bur.

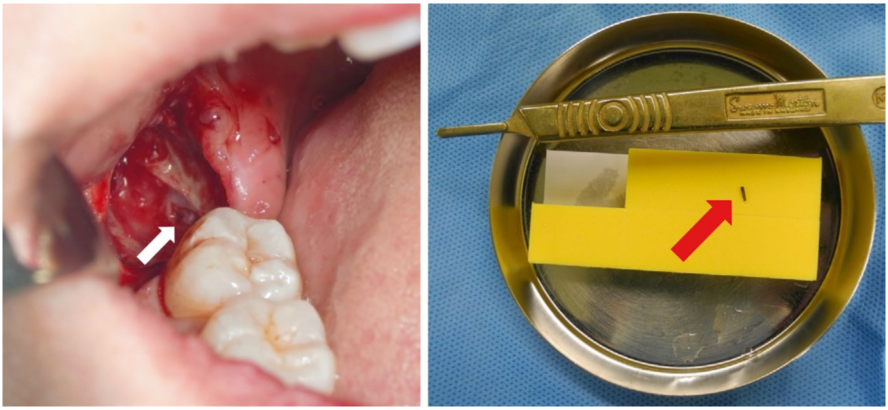


Fig. 25.10 Retrieval of the displaced broken surgical bur (red arrow). Note a perforation of the lingual cortical bone was observed intraoperatively (white arrow)

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Risk Assessment of the Inferior Alveolar Nerve Injury

26

Joe Iwanaga, R. Shane Tubbs, and Soichiro Ibaragi

Introduction

In previous chapters, we have reviewed the surgical and radiological evidence of the inferior alveolar nerve injury. When the overlapping of the mandibular canal and third molar is seen in the panoramic radiography, we assume there is a potential risk of injury of the inferior alveolar nerve. However, previous studies on CBCT have not made any statement of the degree of risk based on the CBCT findings. In this chapter we will propose a new classification of risk of the inferior alveolar nerve injury both in the panoramic radiography and CBCT.

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Risk Assessment of Inferior Alveolar Nerve Injury Using Panoramic Radiography

As the panoramic radiography only provides two-dimensional information, there is no chance to know exactly the relationship between the mandibular third molar and mandibular canal although the Rood's signs seem to be relatively reliable signs. The risk of the inferior alveolar nerve injury can be classified into low and high based on the panoramic radiography (Fig. 26.1). When the high risk is seen in the panoramic radiography, CBCT should be taken to assess further risk, although even the "high"-risk category could include actual "low"-risk group if CBCT would be taken.

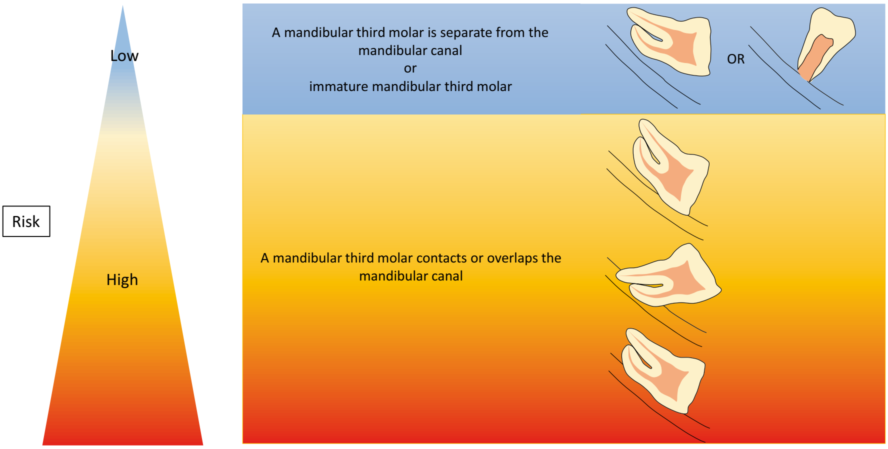


Fig. 26.1 Risk assessment of the inferior alveolar nerve injury using panoramic radiography

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Risk Assessment of Inferior Alveolar Nerve Injury Using CBCT

CBCT can provide three-dimensional information of the relationship between the mandibular third molar and mandibular canal. In this assessment, the risk of injury is classified into four types (Fig. 26.2). If the tooth ever contacts the canal, it is classified into either medium, high, or highest. However, the shape of the canal in coronal view is teardrop or dumbbell shape; this means the canal is compressed by the tooth so it should have higher risk than just being contacted by the tooth. The highest risk is the type entire tooth compressing the canal or inter-radicular course canal.

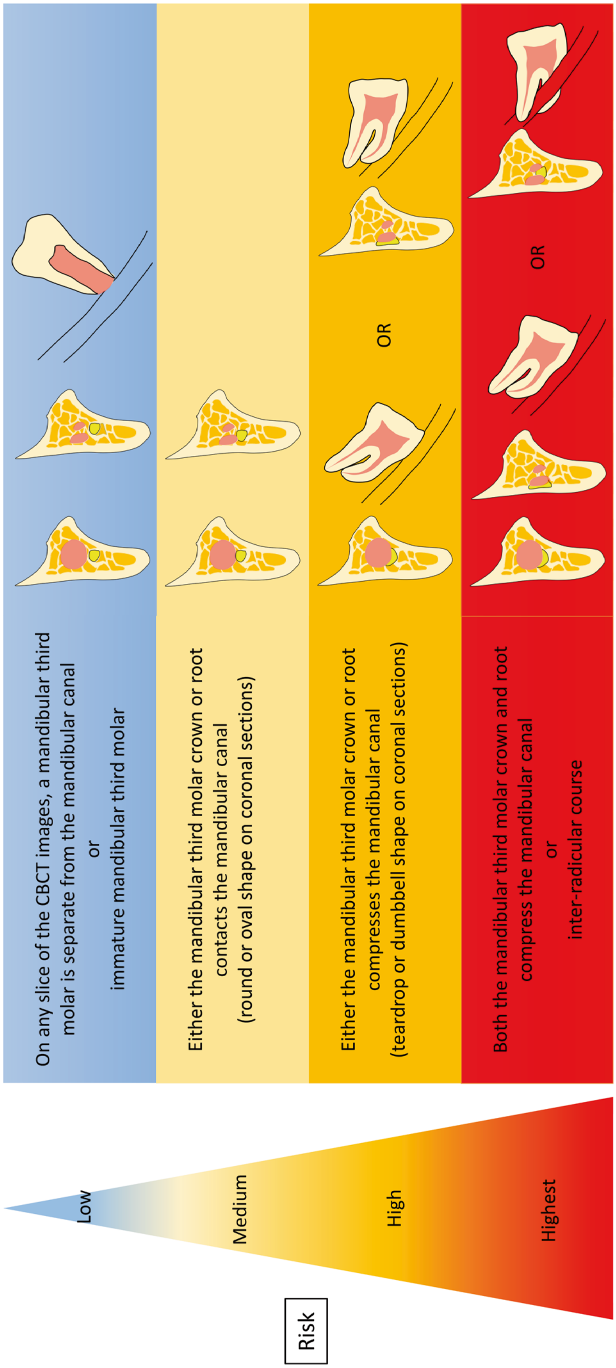


Fig. 26.2 Risk assessment of the inferior alveolar nerve injury using CBCT

Part V

Clinical Case Presentations

Extraction of the Mandibular Third Molar

27

Shogo Kikuta, Yushi Abe, Satoshi Moriguchi, Katsuhisa Matsuo, Kiyosato Hino, Ichiro Hatakeyama, Ken Nakamura, Katsumi Shinozaki, Joe Iwanaga, Soichiro Ibaragi, and Jingo Kusukawa

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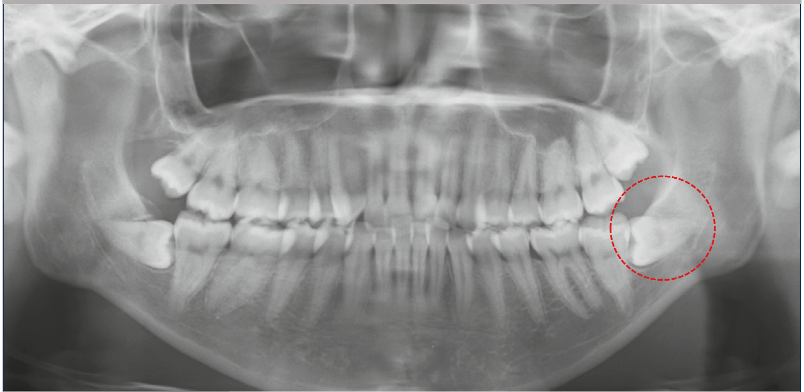
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https://doi.org/10.1007/978-3-031-85466-8_27

Clinical Cases

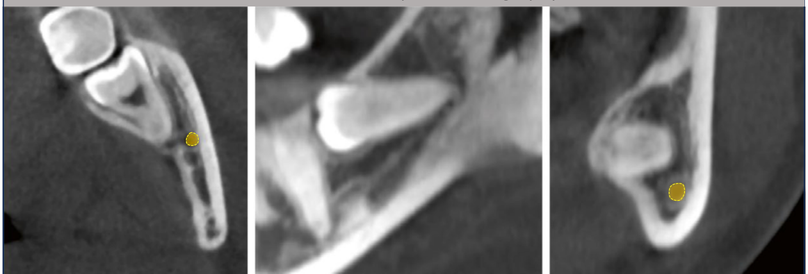
Case 1: 21 y female

Panoramic radiography



Root	Triangle, straight, single
Rood's sign	Interruption of white line of canal
Winter classification	Horizontal
Pell and Gregory classification	Class II Position B

Coned-beam computed tomography

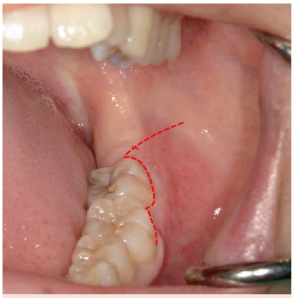


Root	Triangle, straight, single
Mandibular canal	inferior position, oval shape
Lingual plate	Intact
Other considerations	None

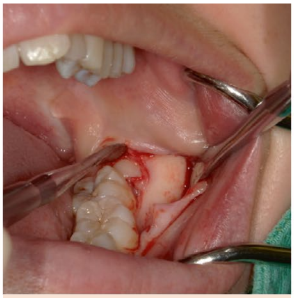
Preoperative notes

- Risk of inferior alveolar nerve injury: LOW

Step-by-step surgical procedure



1. Incision (envelope flap)

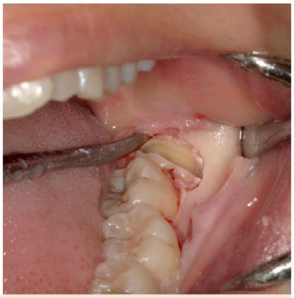


2. Mucoperiosteal flap



3. Bone removal with a round bur





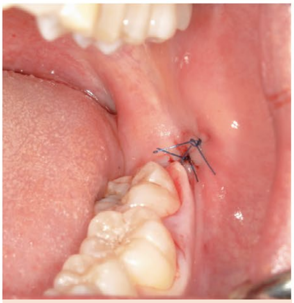
4. Sectioning the crown in buccolingual direction with a diamond bur



5. Tooth luxation



6. Following tooth removal

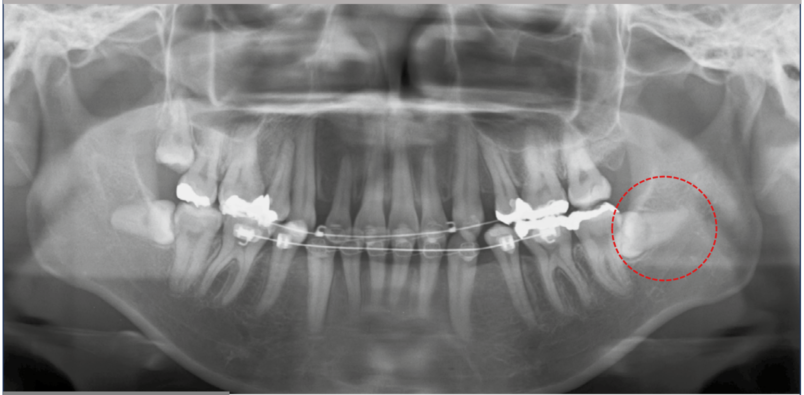


7. Suture

Surgical notes	Exposure of IAN: None Unexpected bleeding: None Postoperative IAN deficit: None

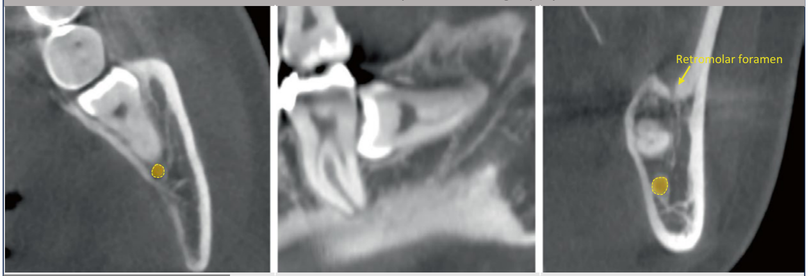
Case 2: 32 y female

Panoramic radiography



Root	Triangle, straight, single
Rood's sign	Interruption of white line of canal
Winter classification	Horizontal
Pell and Gregory classification	Class II Position B

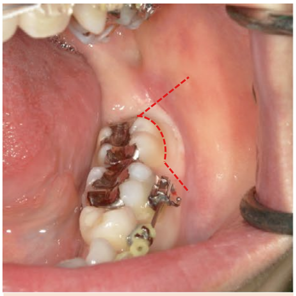
Coned-beam computed tomography



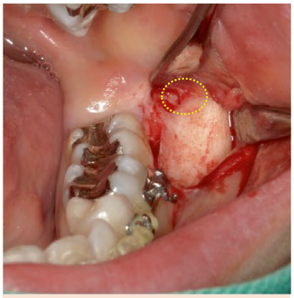
Root	Triangle, straight, single
Mandibular canal	inferior position, oval shape
Lingual plate	Intact
Other considerations	Retromolar foramen

Preoperative notes
- Risk of injury of the retromolar foramen when elevating mucoperiosteal flap
- Risk of inferior alveolar nerve injury: LOW

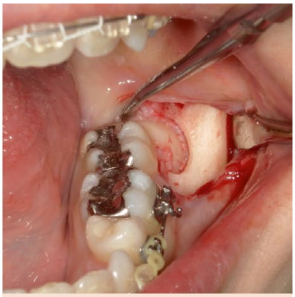
Step-by-step surgical procedure



1. Incision (envelope flap)



2. Mucoperiosteal flap



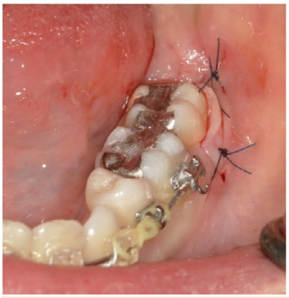
3. Bone removal with a round bur



4. Sectioning the crown



5. Following tooth removal

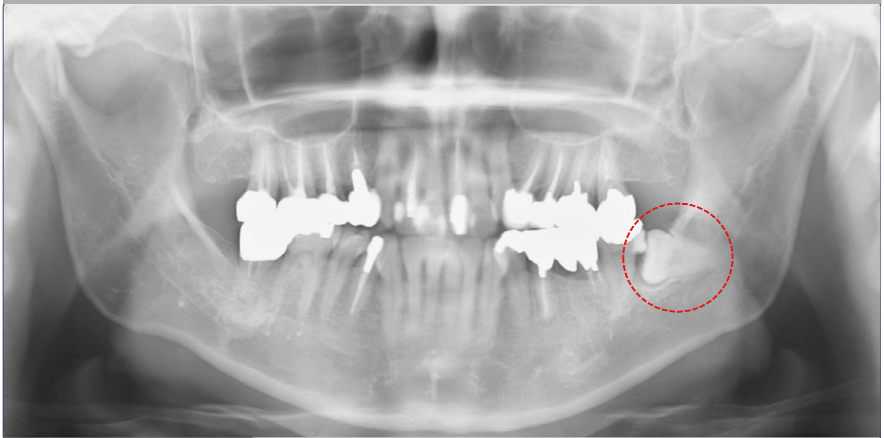


6. Suture

Surgical notes	Exposure of IAN: None Unexpected bleeding: None Postoperative IAN deficit: None Others: Retromolar foramen (yellow dotted circle)

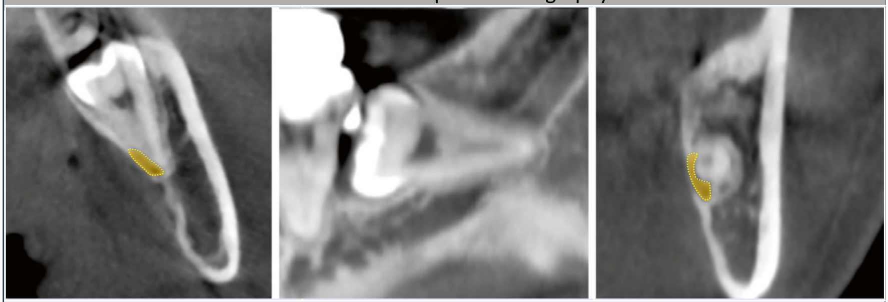
Case 3: 44 y female

Panoramic radiography



Root	Triangle, straight, single
Rood's sign	Interruption of white line of canal
Winter classification	Horizontal
Pell and Gregory classification	Class II Position B

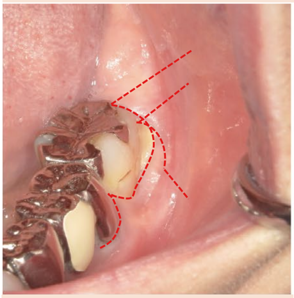
Cone-beam computed tomography



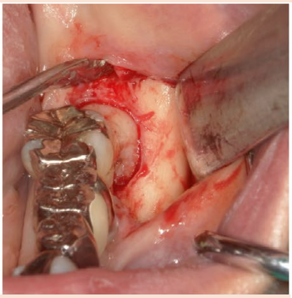
Root	Triangle, straight, single
Mandibular canal	Lingual position, teardrop shape
Lingual plate	Thin
Other considerations	None

Preoperative notes
- Radiolucent area around the crown
- Risk of perforation of the lingual plate when using the elevator
- Risk of inferior alveolar nerve injury: HIGH

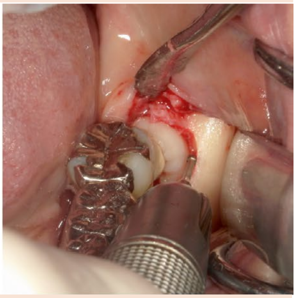
Step-by-step surgical procedure



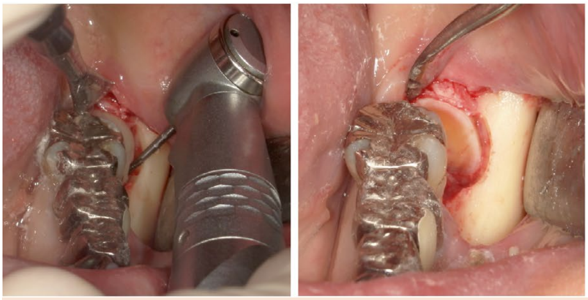
1. Incision (envelope flap)



2. Mucoperiosteal flap



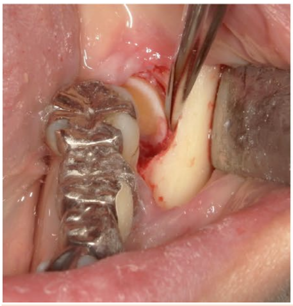
3. Bone removal with a round bur



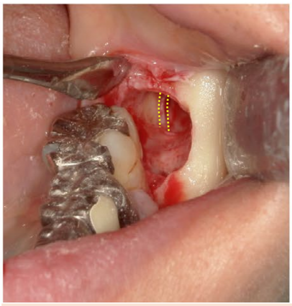
4. Sectioning the crown in buccolingual direction with a carbide bur



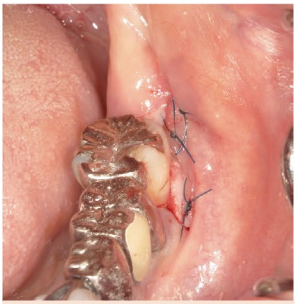
5. Grooving for tooth luxation



6. Tooth luxation



7. Following tooth removal (IAN exposure)

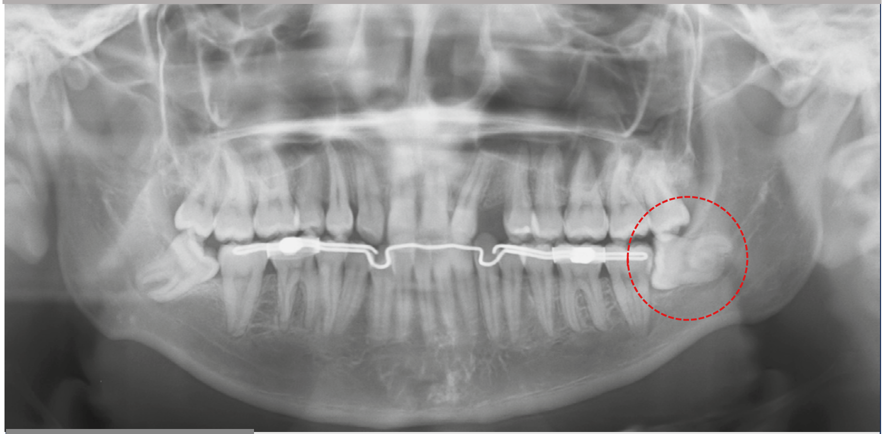


8. Suture

Surgical notes	Exposure of IAN: Yes Unexpected bleeding: None Postoperative IAN deficit: None

Case 4: 24 y female

Panoramic radiography



Root	Curved, double
Rood's sign	Interruption of white line of canal
Winter classification	Horizontal
Pell and Gregory classification	Class I Position A

Coned-beam computed tomography

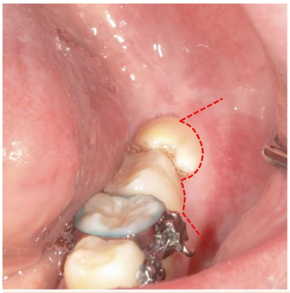


Root	Curved, double
Mandibular canal	Lingual position, teardrop shape
Lingual plate	Intact
Other considerations	None

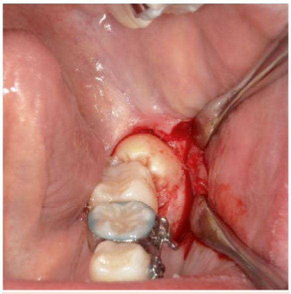
Preoperative notes

- Risk of inferior alveolar nerve injury: HIGH

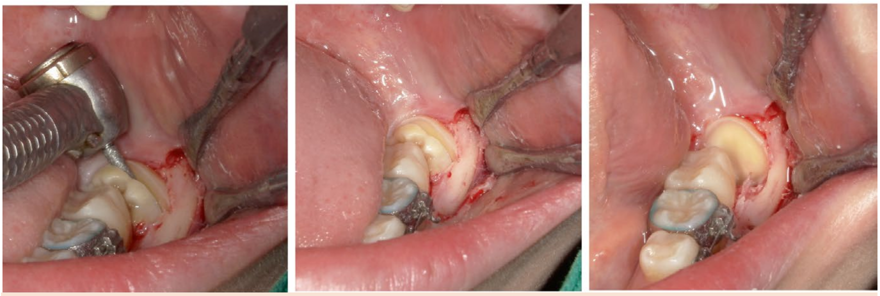
Step-by-step surgical procedure



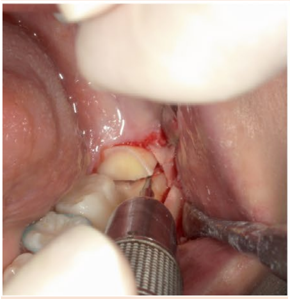
1. Incision (triangular flap)



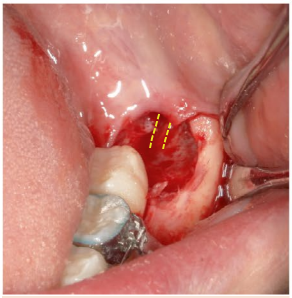
2. Mucoperiosteal flap



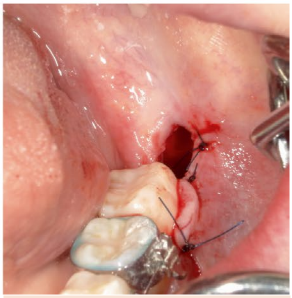
3. Sectioning the crown in buccolingual direction with a diamond bur



4. Root sectioning with a round bur



5. Following tooth removal

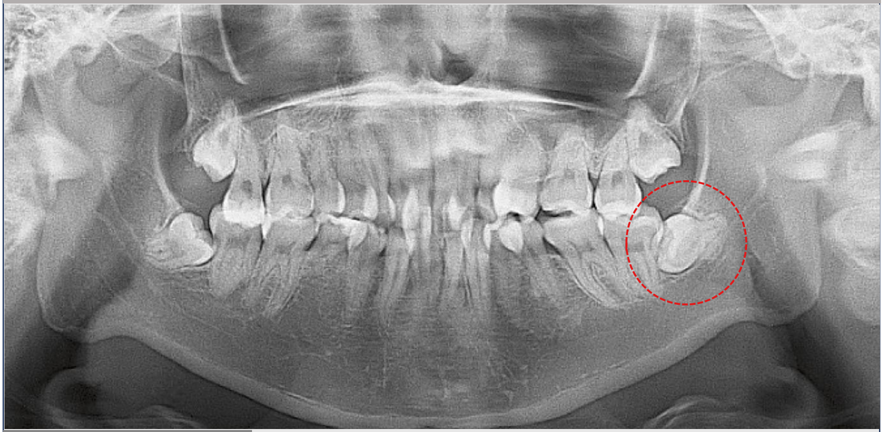


6. Suture

Surgical notes	Exposure of IAN: Yes Unexpected bleeding: None Postoperative IAN deficit: None

Case 5: 23 y female

Panoramic radiography	



Root	Curved, double
Rood's sign	Darkening of root
Winter classification	Unusual(inverted)
Pell and Gregory classification	Class II Position B

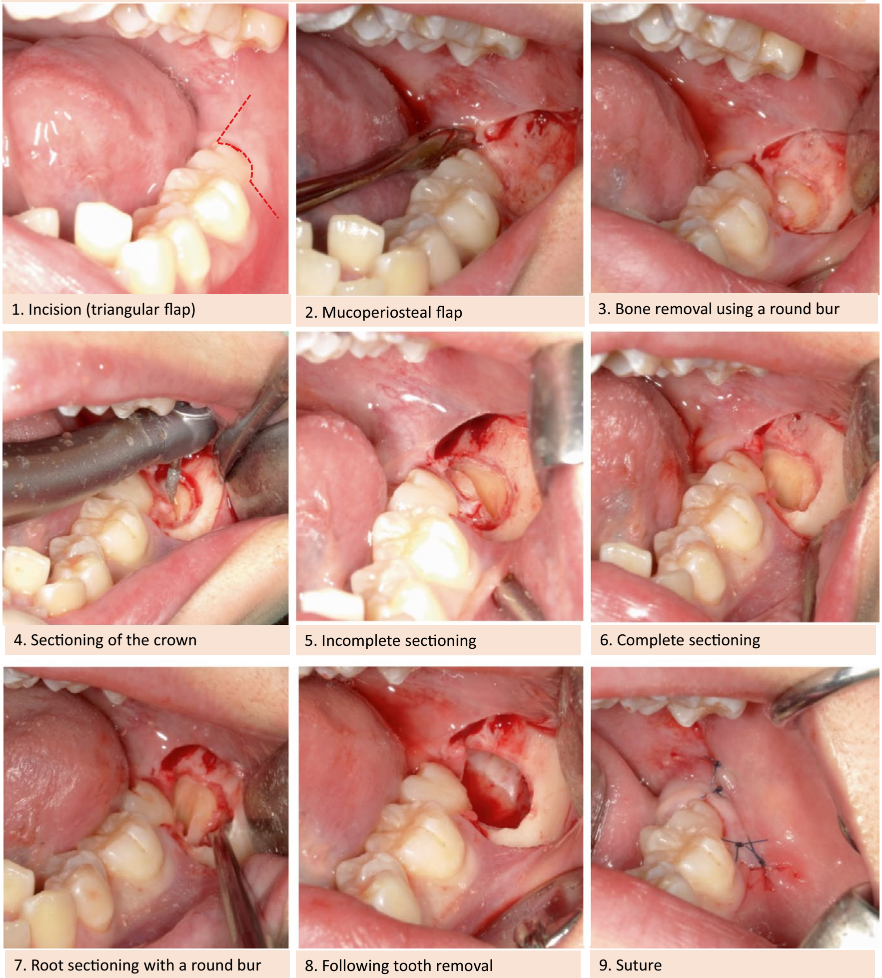
Coned-beam computed tomography	



Root	Curved, double
Mandibular canal	Lingual position, teardrop shape
Lingual plate	Intact
Other considerations	None

Preoperative notes
- Risk of inferior alveolar nerve injury: HIGH

Step-by-step surgical procedure

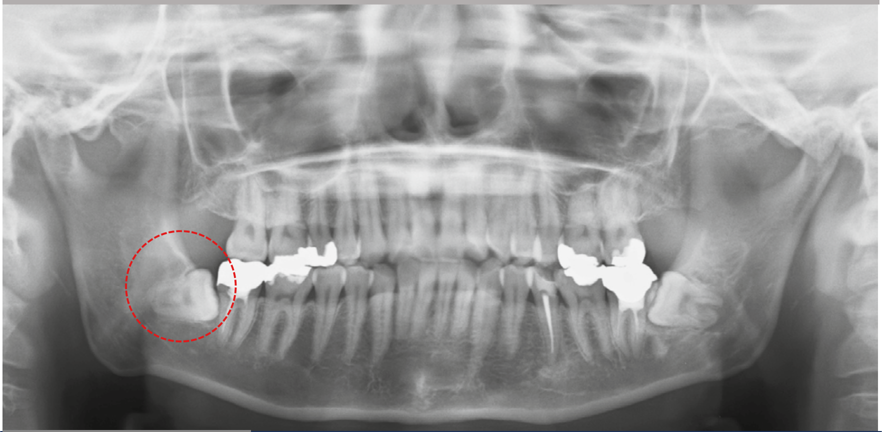


1. Incision (triangular flap)
2. Mucoperiosteal flap
3. Bone removal using a round bur
4. Sectioning of the crown
5. Incomplete sectioning
6. Complete sectioning
7. Root sectioning with a round bur
8. Following tooth removal
9. Suture

Surgical notes	Exposure of IAN: Yes Unexpected bleeding: None Postoperative IAN deficit: None

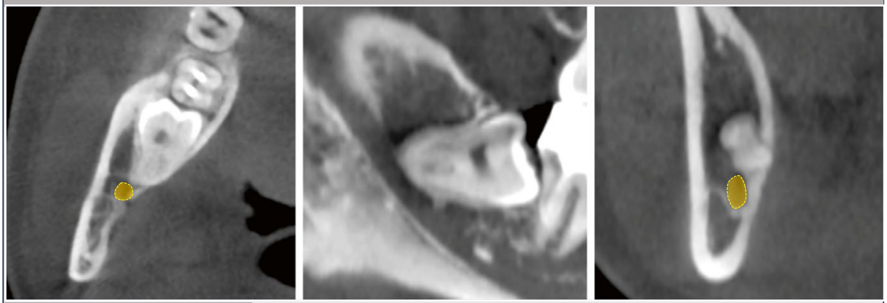
Case 6: 37 y female

Panoramic radiography



Root	Triangle, double
Rood's sign	None
Winter classification	Horizontal
Pell and Gregory classification	Class II Position B

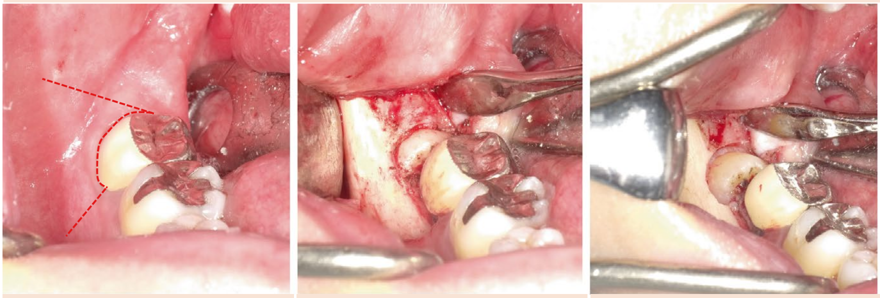
Cone-beam computed tomography



Root	Triangle, double
Mandibular canal	Inferior position, oval shape
Lingual plate	Intact
Other considerations	None

Preoperative notes
- Risk of inferior alveolar nerve injury: MEDIUM

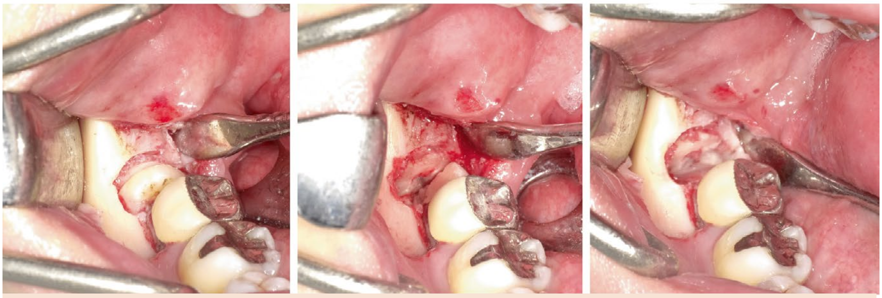
Step-by-step surgical procedure



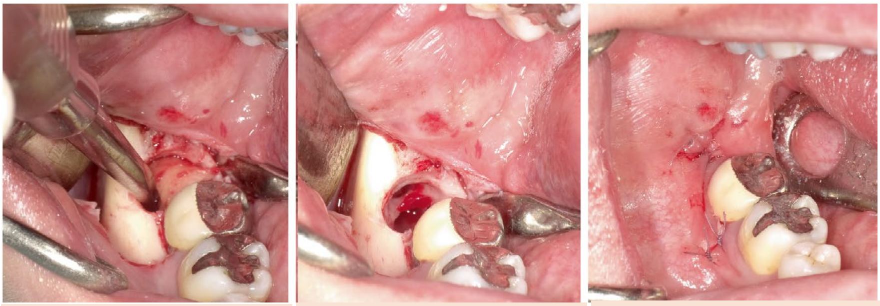
1. Incision (triangular flap)

2. Mucoperiosteal flap

3. Bone removal with a round bur



4. Sectioning the crown in buccolingual direction with a piezosurgery® device



5. Tooth luxation

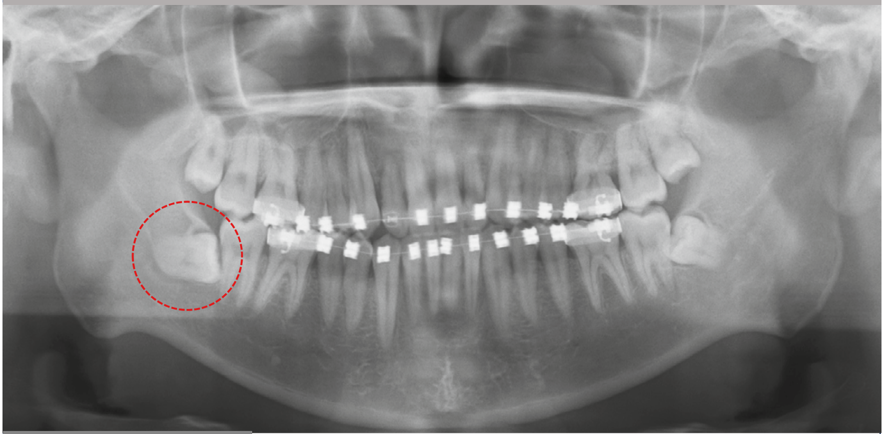
6. Following tooth removal

7. Suture

Surgical notes	Exposure of IAN: None Unexpected bleeding: None Postoperative IAN deficit: None

Case 7: 33 y male

Panoramic radiography



Root	Round, double
Rood's sign	Narrowing of canal
Winter classification	Horizontal
Pell and Gregory classification	Class III Position B

Cone-beam computed tomography



Root	Round, double
Mandibular canal	Lingual position, teardrop shape
Lingual plate	Intact
Other considerations	None

Preoperative notes

- Risk of inferior alveolar nerve injury: HIGH

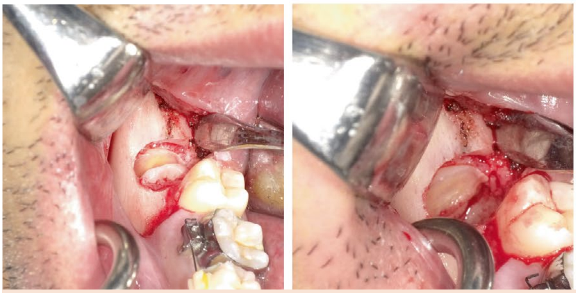
Step-by-step surgical procedure



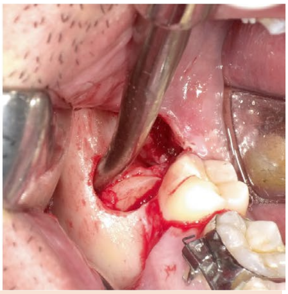
1. Incision (triangular flap)



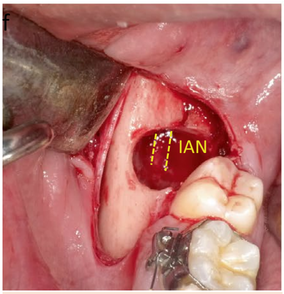
2. Mucoperiosteal flap and bone removal using a round bur



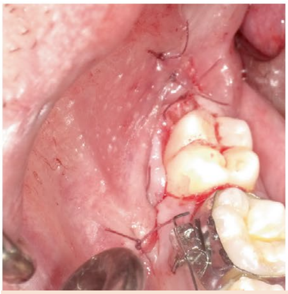
3. Sectioning the crown in buccolingual direction with a carbide bur



4. Tooth luxation



5. Following tooth removal (IAN exposure)

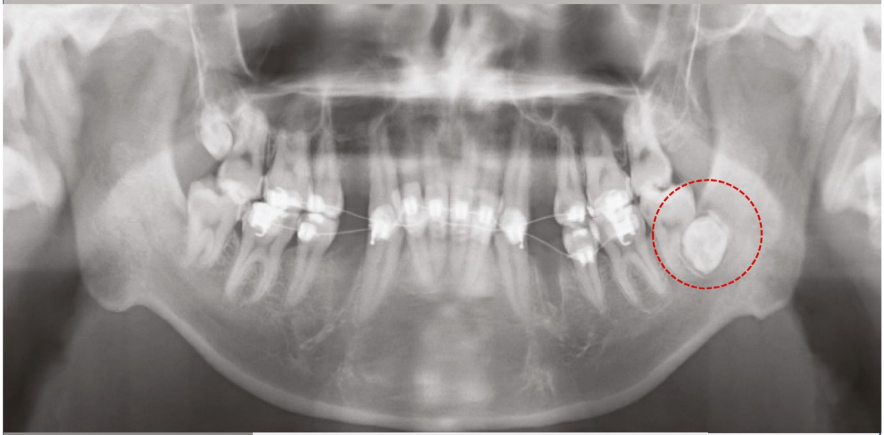


6. Suture

Surgical notes	Exposure of IAN: Yes Unexpected bleeding: None Postoperative IAN deficit: None

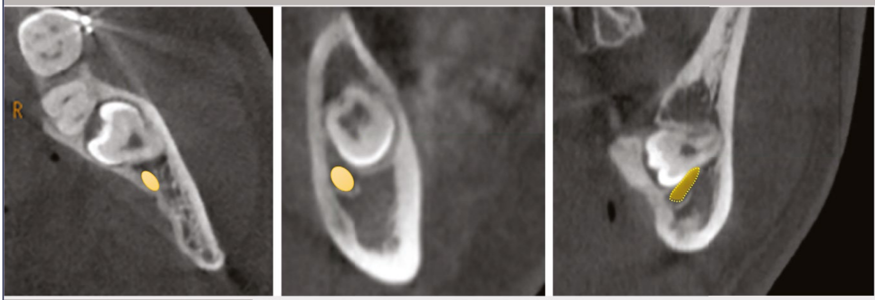
Case 8: 27 y male

Panoramic radiography



Root	Unclear
Rood's sign	Interruption of white line of canal
Winter classification	Lingual
Pell and Gregory classification	Class III Position C

Cone-beam computed tomography



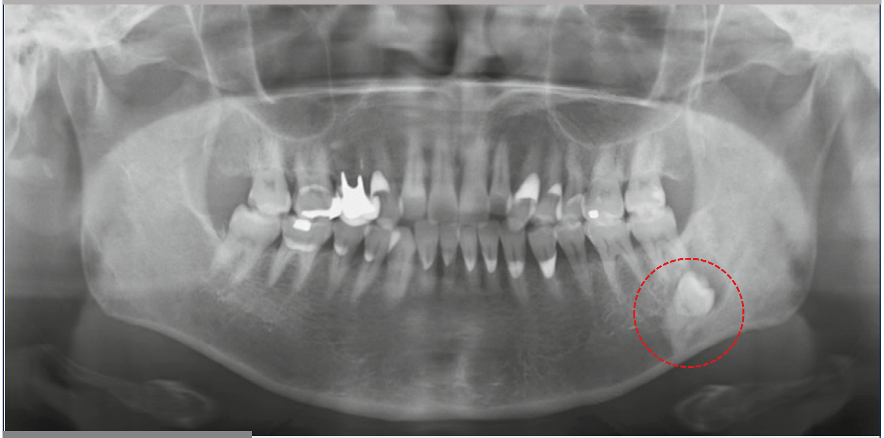
Root	Triangle, curved, single
Mandibular canal	Inferior position, oval shape
Lingual plate	Thin
Other considerations	None

Preoperative notes

- Risk of inferior alveolar nerve injury: Medium

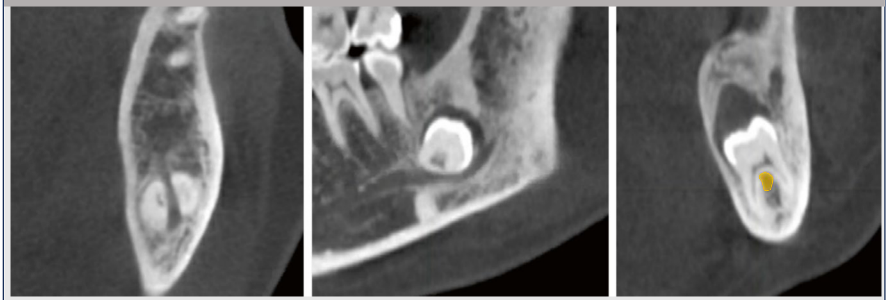
Case 9: 58 y female

Panoramic radiography



Root	Unclear
Rood's sign	Darkening, Interruption
Winter classification	Distoangular
Pell and Gregory classification	Class III Position C

Cone-beam computed tomography



Root	Double
Mandibular canal	Inter-radicular course, round shape
Lingual plate	Intact
Other considerations	Dentigerous cyst

Preoperative notes
- Risk of fracture
- Risk of inferior alveolar nerve injury: Highest

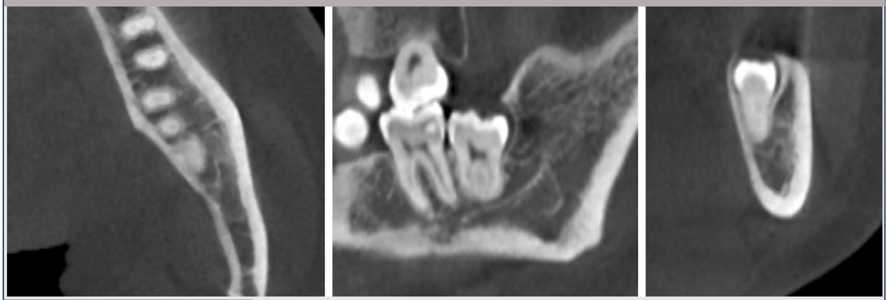
Case 10: 37 y female

Panoramic radiography



Root	Straight, double
Rood's sign	Darkening
Winter classification	Vertical
Pell and Gregory classification	Class II Position A

Cone-beam computed tomography



Root	Enlarged, double
Mandibular canal	Inferobuccal, teardrop shape
Lingual plate	Thin
Other considerations	None

Preoperative notes
- Risk of fracture
- Risk of inferior alveolar nerve injury: High